SECOND REPORT

ON THE

LOCATION OF THE WESTERN PORTION

OF THE

BALTIMORE AND OHIO RAIL-ROAD,

TO A

COMMITTEE OF THE CITY COUNCIL OF WHEELING.

BY

CHARLES ELLET, Jr.

CIVIL ENGINEER.

PHILADELPHIA:

JOHN C. CLARK, PRINTER, 68 DOCK STREET.

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GEORGETOWN, D. C.
May 10, 1850.

To the Rail-road Committee of the City Council of Wheeling:

GENTLEMEN,—I have examined the pamphlet entitled "Reply of the Chief Engineer of the Baltimore and Ohio Rail-road Company," &c., dated February 4, 1850, and addressed, officially, to the President of the Company. This pamphlet contains the revised estimates of the Chief Engineer upon the choice of routes to the City of Wheeling. It admits that there were divers errors in the original comparative estimates condemning the Grave creek route, but contends that those errors were innocent, and generally operated in favour of the rejected line.

I propose to look into these revised calculations in the present Report, and ascertain whether they are more or less deserving of confidence than those which preceded them. But, before engaging in that investigation, it is proper to call your attention to some of the provisions of the Act of March 21, 1850, authorizing the final adjustment of the matters in controversy between your city and

the Baltimore and Ohio Rail-road Company, by their reference to disinterested arbitrators.

By the terms of this law a Board of experienced engineers is appointed to decide upon all matters of difference between the Company and the City of Wheeling. In the language of the Act, "A Board of three competent and "experienced Engineers" shall be appointed by the Governor, "to which Board shall be referred all evidence, "documents and papers relating to the matters of differ- "ence aforesaid; and who . . . . . shall decide upon the "said matters of difference."

The matters of difference thus referred to are recited in the preamble; and are, briefly, that the Fish creek route is alleged by the Company, and the Grave creek route alleged by the city, to be, respectively, the true and proper route, according to a former law and an agreement between the City and the Company. Whatever considerations of a different nature may enter into the decision of this issue, I shall confine myself to the single question of the relative cheapness of the two routes.

Although the City of Wheeling had not directly impeached the fidelity or accuracy with which the surveys of the several routes to Wheeling were made, under the direction of the Company, yet the Legislature, by express enactment, have chosen to open that subject also to investigation; and authorized the Board to institute such additional surveys of the two routes at issue, as they shall deem necessary. Until that may be done, however, I must apply my observations to the surveys already made.

In accordance with the spirit of the Act, which is designed to procure a decision upon "matters of difference," I suppose the Board will accept, as already established,

for the purposes of this investigation, all those points which have been heretofore mutually conceded by the parties. They will scarcely think it necessary to embarrass and complicate the subject by deciding questions on which the parties are themselves agreed.

Now, it will be found, from the "evidence, documents "and papers, relating to the matters of difference afore-"said," that there are divers points which have been mutually conceded, and concerning which there is no longer any difference of opinion between the parties.

These points will, doubtless, be assumed by the Board, upon the strength of the testimony submitted, as the basis upon which both sides are willing to stand, and a fair foundation upon which to rest their own conclusions.

PRELIMINARY FACTS MUTUALLY ADMITTED BY THE PARTIES.

I. As to the construction of the Act of March 6th, 1847, in regard to the amount of trade which should control the estimates.

On this point the Company, by their Chief Engineer, ("Reply," pages 23 and 40), admit their willingness to assume a trade of 250,000 tons and 250,000 passengers per annum, asserting that the increased business will "greatly strengthen their position."

The same point is maintained by the Company's counsel, who asserts (page 4 of his "Statement"), "that the "balance must always be in favour of the Fish creek "route; and the more the higher is the rate of cost per "mile and *the amount of trade.*"

The question of the legal construction of the Act in this particular is thus waived by both parties—each hav-

ing expressed a willingness to assume a trade of 250,000 tons and 250,000 passengers per annum, and each supposing that the larger the trade on which the estimates are based the stronger will be their own position. This, then, is no longer a point of difference to be decided by arbitration.

II. As to the principle of estimating by "equating for "distances."

This is also a question of legal construction, which is earnestly contended for both by the engineer and counsel of the Company. They do not insist, however, that the "equations" should be framed on any particular scale, or that they are tied down by the law to the necessity of assuming that any given number of feet of ascent is equivalent to a mile of distance. On the contrary, the Chief Engineer, in presenting his revised estimates, has abandoned the measure employed in his first comparative estimates, condemning your favourite route, and adopted another with which he says "it is due to the facts and "the truth of the case that the comparisons should be "made."

In his revised computations, which were officially submitted to the President of the Company in February, and officially laid before the Legislature of Virginia, he has, accordingly, discarded his old standard and substituted a new one, which he thinks conforms better "to the most recent and approved experience." (Reply, p. 38—42 et passim.)

These admissions remove another legal difficulty, and I therefore express my entire concurrence. I am willing to adopt a correct mode of "equating distances," as the method by which these comparisons shall be made: and

consent, moreover, that in adopting this principle, the applications shall be in conformity with the facts and the truth of the case, and so as "to make all parts of the "proceeding conform to the most recent and approved "experience."

It is, therefore, mutually agreed that the distances shall be "equated," and that they shall be equated properly, according to correct principles, and "as the facts and the "truth of the case shall require."

III. As to the scale of prices that shall be used to estimate the cost of working.

I am willing, as the Chief Engineer of the Company is, to rest this inquiry "upon the basis of the *actual* "*working of the Baltimore and Ohio Rail-road in* 1848, "*in its transportation department.*"

The counsel of the Company maintains, as above shown, that "the balance must always be in favour of the "Fish creek route; and the more the higher is the rate "of cost per mile." He admits, moreover, that it is not expected that the actual cost of working the road will be as cheap as was represented by the Chief Engineer in the comparative estimates of February 15, 1849—those estimates which condemned the Grave creek route and were contested by your city. But he contends that the errors "operated greatly in favour of the route of high grades," and seems to think that they were therefore justifiable.

The duty of the Engineer was positive. He had no right to estimate incorrectly even for the benefit of the adversary of his employer. You have no right to accept, and cannot honourably accept, such gratuities. The Company are entitled to all the advantage which they can fairly derive from the simple truth; and hence to the be-

nefit of the higher rates established by their own experience. I consent, therefore, to the prices last assumed by the Chief Engineer in the estimates exhibited at pages 42 and 43 of his "Reply," so far as those prices are derived from the Company's Report for the year 1848. I am fully aware that, by taking the scale deduced from the experience of that year, and other assumptions, there results a higher balance against the Grave creek line, under this last of the revised estimates of the Chief Engineer, than under any other which he has presented. Still, it is my wish to rest this comparison upon the facts obtained from the proper experience of the Company, and I therefore willingly surrender all the alleged advantages which had been, for generous purposes, voluntarily conceded by the Company in the fictitious comparative estimates of February 15, 1849.

In the following computations I shall, accordingly, continue to try conclusions with the Chief Engineer "upon the basis of the actual working of the Baltimore "and Ohio road, in 1848, in its transportation depart- "ment."

IV. As to the proper mode of estimating the value of time.

The Chief Engineer has himself removed all difficulty on this head, by stipulating that the trains shall perform their trips in the same time on both routes.

I am willing to make this assumption, and shall ascertain from the best experience and the authority least exceptionable to the Company, what it will cost to work the Fish creek trains fast enough to come out even with those on the Grave creek line.

The parties are then agreed upon the following preli-

minary facts, which, according to the recent Act, being mutually admitted, are not included among those "matters of difference" which are to be decided by the Board of Arbitrators whom the Governor and Executive Council will appoint.

The assumed trade shall be 250,000 *tons and* 250,000 *passengers per annum.*

The estimates shall be made by the process of "equating for elevations and curves."

The distances shall be "equated" correctly, and according to the most recent and approved experience.

The estimates for "working" shall be based upon the results of the actual experience of the Baltimore and Ohio Rail-road for 1848, *in its transportation department.*

The engines shall be supposed to accomplish the trips in the same time on both routes—leaving open the mere question of the effect of the increased velocity on the wear and tear, and consumption of fuel, on the longer route.

These mutual admissions narrow down the subjects in dispute, which were considered in my former Report, to a few primary questions, upon which, after duly hearing the parties, the Board of Engineers will finally decide.

It will be perceived that in discussing these questions I have not noticed any of the errors of the original comparative estimates—those of February 15, 1849. These estimates were demonstrated to be inaccurate in my previous report; and that they are so is admitted both by the engineer who made them and the counsel of the Company. The latter, however, says, in extenuation of the Engineer, that "The object of these estimates being to "show the *relative*, not *absolute* cost of working the "routes, it matters little whether the transportation will,

"in fact, be effected as cheaply or not. It is not expected "that it will," &c.

But as there is nothing in the law which contemplates that these comparative estimates shall be *relatively* true, but *absolutely false*, the Chief Engineer has, in my opinion, very properly abandoned his original ground, and substituted new calculations, purporting to be based on actual experience, and presenting positive results.

It is these new and revised estimates which I propose now to discuss.

OF THE EQUATION OF DISTANCES.

One of the leading purposes of this "Reply" of the Chief Engineer, is to show that the merits of the rival routes to Wheeling should be compared in accordance with a certain principle which he designates the principle of "equation of distances." Our first duty is then to examine the structure of this "equation;" for, if your rights are to be measured upon an empirical scale, it is proper that you should be satisfied that that scale is legitimately obtained and rightly adjusted.

Now, by the expression "equation of distance," the Chief Engineer means to designate a rule, by the aid of which, when he knows the ascents and descents of a line of rail-road, he is able to determine how many miles of level road would be equal, in its effect on the cost of motive power, to the ascertained amount of ascent and descent. The result of this preliminary investigation showed, according to the often quoted Report of 1838, that an ascent of $26\frac{4}{10}$ feet is equivalent, in the expenditure of power which it involves, to one mile of distance.

The original comparative estimates of February 15, 1849, which condemned the Grave creek route, were based on this increment.

But we learn from the "Reply" of February 4th, 1850, that new light has recently been shed upon the mind of the Chief Engineer, on this subject, and he now thinks—if he has not since improved his opinion—that an ascent of 20 feet is just equal to a mile of distance. This is what he calls an "equation."

It is with a feeling of extreme regret that I find myself compelled to engage in an examination of the process which has led to these results, and to expose a series of errors which has spread through all the reports and field duties of the Chief Engineer of the Baltimore and Ohio Rail-road, for a period of twelve or fifteen years.

The first step in this operation of equating distances, is to determine the power necessary to move a locomotive engine and its train upon a level road. This part of the subject the Chief Engineer despatches, in his "Reply," with singular brevity—assuring the President that "*friction is the sole resistance encountered on the level and* "*straight road.*" He does not state in this connexion what he intends shall be understood by "friction;" but in the Report of 1838, to which reference is made, the demonstration is given in detail. Friction is there explained to mean the friction of *the cars only*, the report coolly stating "that the resistances due to the friction of "the *engine and tender* are left out of the question, and "the *useful effect* of the machine alone considered. This "omission simplifies the propositions without taking from "their truth." [See Note A.]

I cannot consent to any such *simplification* of an important mathematical proposition, as that which is here so unceremoniously assumed.

The question proposed for investigation is to find the resistance to the progress of a locomotive and its train along a level road; and then to ascertain what must be the inclination of a plane parallel with which the gravitation of that engine and its train will be just equal to the ascertained resistance on the level. The power required to ascend this plane will, of course, be double the power required to move the train at the same velocity on a level road.

To solve this problem the Chief Engineer of the Company first ascertains the friction of the *cars* on a level road, but leaves out the resistance of the engine and that of the tender, in order, as he explains it, to get at the "useful effect;" and he then ascertains the inclination of the plane on which the gravity of the cars, engine and tender, taken altogether, shall be equal to the friction of the *cars alone* on the level road.* The ascent of this plane per mile is the scale by which he then "equates" his distances.

No engineer will expect me to show what is wrong in this singular process. The only discovery that could do credit to any one would be to find something right in such extraordinary reasoning.

But the *effect* of this remarkable operation is worth looking into before we proceed further with the discussion. By leaving out the resistances of the engine and

* It is rather surprising that the Chief Engineer should have included the friction of the *cars* even. To arrive at the useful effect—as he understands that process—he should have confined himself to the friction of the *goods*.

tender on a level road, we underrate the actual power required to move the train on a level, in ordinary practical cases, from three-fourths to four-fifths—or, we deduce for the power which is usually called into action in moving the train on a level line, a quantity which is but one-fourth or one-fifth of its actual value; and, consequently, when we determine the grade down which the force of gravity alone is equal to the power required to move the train at the assumed velocity on a level, we obtain a grade of which the inclination is but one-fourth or one-fifth as steep as we should have found by taking the whole power needed on the level line. The error of the Chief Engineer originates with his first thought—the determination of the power required to propel a locomotive engine and its train *upon a level road*—and this leading error has spread through all the subsequent deductions, vitiating and falsifying them all.

OF THE POWER REALLY REQUIRED TO MOVE A TRAIN ON A LEVEL ROAD.

We come now to the question, what are the resistances to be overcome in moving a train upon a level road? What are the duties which the steam, and hence the fuel, have to perform?

The reply depends obviously in part upon the construction and size of the locomotive. But we will first assume that the application is made to a freight engine of the following proportions:

Weight of engine, - - - -	22 tons of 2000 lbs.;
Diameter of cylinders, - - -	17 inches;
Area of both cylinders, - - -	454 square inches;

Length of stroke, - - - -	2 feet;
Diameter of drivers (coupled wheels), -	$4\frac{1}{2}$ feet;
Friction of engine, without train, - -	440 lbs.;
Additional friction, per gross ton, - -	1 lb.;
Weight of tender, - - - -	15 tons.

Now, before this, or any other locomotive engine can move a hair's breadth, there must be a power applied to the two pistons equal to the atmospheric pressure, or nearly 15 lbs. per square inch, upon their total area.

Until this force is applied the engine cannot budge. But the area of the pistons is 454 inches, and 15 pounds per inch on that surface, shows a pressure of 6810 lbs. necessary to be applied to the pistons to balance the atmospheric resistance alone.

All the other forces that resist the motion of the train are applied at the circumference of the wheel; and we should therefore ascertain the equivalent value of this pressure on the pistons when applied at the same point.

While the circumference of the wheel makes one full revolution, the piston completes two strokes, or traverses a space of 4 feet. The circumference of the wheel is $14\frac{137}{1000}$ feet, and the pressure upon the piston when transferred to the perimeter of the wheel will, therefore, be reduced to

$$\frac{4}{14.137} \times 6810 = 1927 \text{ lbs.}$$

It thus appears, that, merely to move the pistons against the atmospheric pressure, requires a force of 1927 lbs. The Chief Engineer forgot this item.

But when this pressure of 6810 lbs. is applied on the pistons—or its equivalent, 1927 lbs., at the circumference of the wheel—the engine will not move. The friction of

its own machinery must yet be overcome. This friction has been found to be about 14 lbs. per ton of 2000 lbs., for uncoupled engines. I do not know of any experiments on the proper friction of the eight-wheel coupled engines of the Baltimore road. But it cannot be less than 20 lbs. for each ton of the weight of the engine. I shall assume that number, which, if disputed, may be corrected by experiment.

This friction, at 20 lbs. per ton, for an engine of 22 tons weight, will be 440 lbs. This item is also left out of the Chief Engineer's calculations.

Still, even when we apply this additional force, the train cannot be moved. We must yet start the tender before we can spare any power to move the cars. For, notwithstanding the sage expedient of the Company's distinguished engineer, who, in his computation, leaves behind the locomotive and tender, for the purpose, as he informs the Board, of increasing the *useful effect*, it is perfectly certain that the train cannot get along, be the ground ever so level, without the engine, nor the engine without the tender. We may as well attempt to ride in our carriage, leaving the horses behind to save feed, as to ride in the cars on a level road leaving the locomotive and tender behind to avoid resistance and economize fuel.

The engine must draw the tender along with it. The weight of the tender is 15 tons; its friction, on an even road, and in fair weather, will be about 8 lbs. per ton. The resistance of the tender is, therefore, 120 lbs. The calculation of the Chief Engineer neglects this item too.

We come now to the friction of *the cars*, which the Company's engineer asserts is "the sole resistance encountered on the level and straight road."

The average weight of freight in the trains carried on the Baltimore and Ohio road when the trade was about 60,000 tons per annum, was 22 tons. But in the year 1848, when the business had reached 180,000 tons, and the Company had a fair supply of first class engines, the trains contained an average of 39 tons.

In the present computations, I shall assume 40 tons for the average load; and for the corresponding weight of cars, the proportion adopted by the Chief Engineer, $1\frac{1}{8}$ tons of cars for each ton of freight. This produces for the total load behind the tender, 85 tons gross.

The friction of the cars, at 8 lbs. per ton, is therefore 680 lbs. This is the solitary item which the Chief Engineer's computation embraces.

Now, these are the resistances encountered when the train is moving at a very slow rate on a level road. But, when the speed is increased, the pressure of the air upon the engine and house cars, becomes an appreciable element of resistance. If we estimate the *frontage* of the train as equal to 100 square feet,* the resistance of the air for the average velocity prescribed by the Chief Engineer for the freight trains on the Grave creek line,—$10\frac{1}{3}$ miles per hour,—will be, according to Smeaton's table, about 50 lbs. The actual resistance from this cause is undoubtedly greater—for the experiments of Smeaton were made on a plane surface, and do not enable us to account for the adhesion of the air along the sides of the train.

Summing up these several quantities, we find for the total resistance to this engine and train,

* The actual area of front for any engine and one car, is less than 100 square feet. But the calculation should include also the area between the floor of the cars and the ground.

Atmospheric pressure on the pistons, - -	1927 lbs.
Friction of engine, without load, - -	440 „
Friction of tender, - - - -	120 „
Resistance of air in front of train, - -	50 „
Friction of cars and loads, - - -	680 „
Total resistance on a level road, - -	3217 lbs.*

A large freight engine, therefore, drawing an average load, cannot proceed at 10 miles an hour along a straight and level road, without overcoming a resistance of 3217 lbs.; while the Chief Engineer of the Baltimore and Ohio Rail-road Company, has only been able to detect the resistance caused by the friction of the cars themselves, or, in this instance, 680 lbs.—but little more than *one-fifth part* of the total resistance actually overcome.

OF THE GRADE ON WHICH THE FORCE OF GRAVITY ALONE WILL EQUAL THE RESISTANCE ON A LEVEL.

It will be readily conceived, that when the Chief Engineer had committed an error of nearly 400 per cent., in estimating the value of the force required to move a train upon a level line, he would, of necessity, be led into a similar error in determining the slope on which the component of gravity parallel therewith would be equal to this force. The resistance on a level road being improperly computed, the resulting inclination must, of necessity, also be wrong.

To determine the inclination on which the resistance is doubled, we require, first, to know the gross weight of the train of which the gravitation is to be ascertained.

* This calculation neglects the *additional* friction of the engine *due to the load*, because the item is not only very small, but also of a character not to affect the result in any sensible degree.

The engine weighs	-	-	22 tons.
„ tender „	-	-	15 „
„ cars „	-	-	45 „
„ freight „	-	-	40 „
Total weight of train,	-	-	122 tons or 244,000 lbs.

On a slope of 1 in 76, the weight of this train decomposed in the direction of the plane, will be just equal to the resistance on a level road, or 3217 lbs. This slope corresponds with a grade of 70 feet per mile.

It thus appears that, when freight engines of the best class are used, and the weight of the train is equal to that of the average trains on the Baltimore road, the power which is required to propel the train on a straight and level line, is not doubled by an ascending grade, unless the inclination of that grade amount to 70 feet per mile. But, in announcing this result, it is proper to state that it is not applicable to every engine, nor to every train. On the contrary, the "equation of distance" varies with every engine and every load.

As an example, we may determine the "equation," or the ascent in feet per mile for a passenger engine of medium class.

Proportions of the Engine.

Weight of engine, - - - -	16 tons;
Diameter of cylinders, - - -	16 inches;
Area of the two cylinders, - - -	402 square inches;
Length of stroke, - - - -	1.66 feet;
Diameter of drivers, - - -	5 feet;
Friction of engine, without train, - -	260 lbs.;
Additional friction per ton, - - -	1 lb.;
Weight of tender, - - - -	10 tons;
Velocity per hour, - - - -	25 miles.

With this engine, we shall find, by going through the preceding calculations, for the

Atmospheric pressure on the pistons, - - -	1280 lbs.
Friction of engine, two coupled wheels, - -	260 „
Friction of tender, - - - - -	80 „
Resistance of air at 25 miles per hour, - -	300* „
Friction of cars and load with 60 passengers—40 gross tons,	320 „
Total resistance on a level road, - -	2240 lbs.

Which is *seven times* as great as the Chief Engineer's calculation makes it appear.

The total weight of this train will be as follows:

Engine, - - - -	16 tons;
Tender, - - - -	10 „
Cars and loads, - - -	40 „
Total weight of train, -	66 tons, or 132.000 lbs.

The component of the weight of this train, parallel with a plane of which the slope is 1 in 59. will be equal to the resistance which it encounters on a level. This slope—the slope of double resistance—is therefore $89\frac{1}{2}$ feet per mile.

We thus find that to ascend a grade of 20 feet per mile does not require double the power that is expended in moving the train at the same velocity on a level road—as is assumed in the last revised calculations of the Chief Engineer. There is no foundation for this assumption; it must fall, and with it must come down the equally monstrous proposition, which is derived from it, that the Grave creek line, just $41\frac{305}{1000}$ miles long, must be re-

* At the speed assigned by the Chief Engineer for the Grave creek line ($18\frac{1}{2}$ miles per hour), this item would be 160 lbs.

garded as just $82\frac{3}{10}$ miles long. This is one of the many fatal errors which pervade the calculations of the Chief Engineer, and which it becomes my most unpleasant duty to expose.

We find, by carrying out the computations, that a first class freight engine, with an average load, requires a grade ascending at the rate of 70 feet per mile, before the force of gravity opposing the ascent will be equal to the sum of the resistances encountered on a level road, and, consequently, before the action of the engine will be twice as great as it would be on the level: and that an ordinary passenger engine will require an ascent of $89\frac{1}{2}$ feet per mile, before the power exerted will be double the power actually required on a level line.

The error of the Chief Engineer is, therefore, to the fact, in the one case, as 20 is to 70, and in the other case, nearly as 20 is to 90. The average error is as 1 to 4.

As it will be convenient, in some of the following calculations, to have an average expression for the slope on which the force of gravity is equivalent to the resistances on a level road, I shall, in such cases, assume for that mean value, a grade of 80 feet per mile. I need here, however, make but one application of this average.

In the "Reply" of the Chief Engineer he assumes that the Grave creek route—of which the measured length is $41\frac{305}{1000}$ miles—is virtually increased in length by its curves and grades, so that it must be regarded, in estimating the cost of working the line, as $82\frac{362}{1000}$ miles long. Of this enormous and gratuitous addition to the true distance, no less than 33 miles are attributed to the influence of the grades—a conclusion which is reached by estimating 20 feet of ascent, as equivalent, in its demand on the

power, to one mile of distance. But, if this calculation had been correctly made, and an average rise of 80 feet had been taken as the equivalent of a mile of level road, this increase would have been reduced from 33 miles down to $8\frac{1}{4}$ miles.

The steep grades of the Grave creek line all occur within a space of 13 miles; so that, if it required two engines *every trip*, on that part of the route, to do the work which one engine can accomplish on the grades of the Fish creek line, the power would only be doubled *on these* 13 *miles*. And even in that case we would only be authorized to add 13 miles, instead of 33 miles, to the length of the line; but it will presently be shown that two engines will be very rarely required, and that when they are required they will be able to command much heavier trains on the steepest ascending grades of the Grave creek line than one engine can draw at the rates of speed agreed on, up the steepest grades of the Fish creek line. This subject will be discussed under the head of heavy trains and *assistant power*. We are now treating only the question of cost, and "equation of distance," for those average trains which are taken through both lines by a single engine, and without any extra aid.

Now, I am not to be understood to intimate, by any result which has been announced, that the actual cost of working the Grave creek line is increased by the grades found on that line, even in the item of power, an amount sufficient to justify the addition of $8\frac{1}{4}$ miles to its length. Far from it. That result could only apply to a particular case—*the case of a rail-road which is all up hill both ways*. We have yet examined but one item of the Chief Engineer's bill of errors. We have only traced the

"equation of distance" on ascending grades, and have taken no account of the descents. But, in the practical application of this theory, other vagaries equally important and not less incomprehensible, are developed. And it is a singular fact—but a fact which I do not wish to discuss here—that the resultant of *every error* in the estimates of the Company's Engineer, falls on the same side of the scale, and is calculated to make your interests strike the beam.

OF THE "EQUATION OF DISTANCE" WORKING ON DESCENDING GRADES.

The next proposition of the Company's Engineer—which received full consideration in the estimate by which he added 41 miles to the length of the Grave creek line—is equally characteristic and remarkable. This proposition sets forth that the power required to *ascend* a plane which rises 20 feet in a mile, is twice as great as would be required if the engine traversed a mile of level road; but that, when the same engine and the same train *descend* that same grade, the power required to move them is not, practically, any less than it would be on a level road. When an engine ascends a grade the power is increased, and this increase, or rather *its quadruple*, is charged against the grade; but when the same engine returns, with the same train, the power receives no credit for the descent. Even when the engine and train can run down without the application of any force whatever, it is contended that there is really no saving of power due to the descent.* In short, the engine is assumed to expend

* The level and descending grades of the Grave creek line, generally streteh over a space of 3 miles, and from that up to 17 miles, continuously. But the steep grades are very short.

just as much power when doing nothing on descending grades, as when hard at work.

The Chief Engineer of the Baltimore road has discovered an anomalous equation—an algebraic formula which will not work both ways; an expression, in fact, which will only work *up hill.*

As a consequence of the stubborn nature of this mathematical principle, when a train proceeds to the west, on the Grave creek line, and ascends a total elevation, or sum of elevations, of $524\frac{7}{10}$ feet, it is charged with that amount of ascent at the rate of one mile for every 20 feet; but when the same train, continuing westwardly, afterward descends $797\frac{7}{10}$ feet, the equation makes no allowance for that relief, but works on blindly, as if descending grades were of no consequence whatever.

In short, all the Chief Engineer's computations take into the account ascents only, and treat all the descents as the native inhabitants of America treated the supernumerary days of their calendar—as *waste.*

Now, I propose to show that the total power required to propel an average train from east to west is 4 per cent. *less* on the grades of the Grave creek line than would be required on a level road of the same length;—or, in other words, that the descent of $797\frac{7}{10}$ feet more than compensates, in the expense of power or consumption of fuel, for the ascents of $524\frac{7}{10}$ feet, for every engine that has power enough to carry its train up the steepest grades of that line. I shall treat of the larger trains, requiring assistant power, elsewhere.

OF THE POWER ACTUALLY EXPENDED IN PROPELLING A TRAIN THROUGH THE GRAVE CREEK LINE.

The length of the Grave creek line is $41\frac{305}{1000}$ miles. The power required to propel a freight train with an average load, on a level, has been found to be 3217 lbs. If the whole line were straight and level, the power consumed in taking the train through it, would be—

3217 lbs. moved $41\frac{305}{1000}$ miles = 132,878 lbs. moved 1 mile.

We have next to compare this power with that which will be expended in traversing the grades of the Grave creek line, as it is actually laid out.

In computing this latter quantity, it is clear—and too clear to require demonstration—that to the power needed to move the train on a level road, we must add for each ascending grade, an amount precisely equal to the gravitation of the train down that same grade. But every reader familiar with mechanical principles will perceive, that this addition is equal to the absolute weight of the whole train multiplied into the absolute ascent expressed in miles. And we might adopt that process. But there are some advantages to be gained by selecting a different mode of calculation, and decomposing the weight of the train in the usual manner.

If the descending grade exceed the angle on which the force of gravity is just equal to the resistance of the train—then that portion of the descending grade which is greater than the limit which denotes the equilibrium, is not available in saving power; for, beyond that limit, and as we approach the slope where the force of gravity so far exceeds the resistances, that the acceleration would

be dangerous, the brake must be applied, and we therefore lose the advantage of that part of the descent. There are cases certainly—and they occur on the Grave creek line as now laid out—where such acceleration is admissible, either because it is slight, or because the descending grade which produces it is immediately followed by one of less descent, or by a level space, or by an ascending grade, where the excessive speed, if acquired, would be promptly reduced.

The first point to be determined, in estimating the value of the descending grades, is the slope on which the force of gravity and the resistances to the progress of the train, when not actuated by the force of steam, are in equilibrio. For this purpose we may admit a speed of 25 or even 30 miles an hour as entirely safe. These several resistances will then be as follows:—

Friction of the engine, - - - -	440 lbs.
„ „ tender, - - - -	120 „
Resistance of the air (average), say, - -	250 „
Friction of the cars and load, - - -	680 „
Total resistance to a freight train descending by the force of gravity, - - -	1490 lbs.

The total weight of this train has been shown to be 244,000 pounds; the gravity will therefore be equal to the resistance on a grade of 32¼ feet per mile. This is not the angle of repose, but it is the slope on which the motion of the train will be neither accelerated nor retarded, but uniform. The grade of *repose* is 27 feet per mile.

The same computation applied to the circumstances of a passenger train—adopting 30 miles per hour as an admissible velocity—gives, for the gradient of uniform mo-

tion, $39\frac{6}{10}$ feet per mile. In cases where, in this paper, it becomes convenient to use an average expression for the value of this grade, I shall adopt the mean between these results, or 36 feet per mile.

We may now proceed to ascertain the power required to propel a train over the Grave creek line, of which the gradients, according to the survey of the Chief Engineer, are given in the "Statement of Thomas Swann, Esq., President of the Baltimore and Ohio Rail-road Company, laid before Committee on Roads and Internal Navigation of the Virginia Legislature."

The total descent, going west, is $797\frac{7}{10}$ feet. But of this total descent a portion is found on grades exceeding the slope of uniform motion, or 36 feet per mile. We must, therefore, determine the amount of fall which occurs under these circumstances, and deduct it from the total fall to obtain that portion of the descent which is available in saving power.

It will always be recollected that the engines here provided are capable of commanding their trains on every grade; and that the only question, now, is to ascertain how much the power, or cost of fuel, is increased by the ascents and diminished by the descents, of the line, for engines which are thus competent to overcome all the grades without assistance.

The only deductions to be made from the total descent, going west, occur on two grades, each of $79\frac{2}{10}$ feet per mile, of which the joint length is 3.665 miles.

Hence we have,—

$\frac{3665}{1000}$ miles $\times (79\frac{2}{10} - 36) = 158\frac{4}{10}$ feet, for that portion of the total descent which is unavailable in saving power.

The total descent, going west, is - - - -	797.7 feet
Of which there is unavailable, as above, - - -	158.4 „
Leaving for the descent which *is* available in saving power,	639.3 feet
From this available descent, we deduct the total ascents, -	524.7 „
And we obtain for the excess of the available descents over the ascents, for all trains going west, - -	114.6 feet

The length of the Grave creek line is 218,090 feet; and, consequently, the assistance derived from the grades will exceed the resistances which they occasion, by the fraction

$$\frac{1146}{2180900}$$

multiplied into the weight of the train.

This operation performed for the tonnage train, produces 128 lbs. for the excess of the value of the aid derived from the descending grades over that of the increased resistance occasioned by the ascending grades, on the trains going west.

The resistance to the freight train on a level, is - -	3217 lbs.
Deducting aid derived from gravitation, - - -	128 „
And we have for the power actually required, going west,	3089 lbs.

3089 lbs. moved $41\frac{305}{1000}$ miles = 127,591 lbs. moved 1 mile.

This is fully 4 per cent. less than the power required on a level line of the same length.

It is not necessary to repeat these calculations for the passenger train. The result will be essentially the same.

But a similar computation made for the trains going east will lead to a very different conclusion. There, the ascending grades not only exceed the descending, absolutely, but a larger proportion of the total descents, as

the line is projected, is thrown into grades exceeding in steepness the limit of uniform motion. Thus we find, descending to the east, the following deductions for unavailable descents—

$4\frac{196}{1000}$	miles	$\times (79.2 - 36) =$	181 feet.
$1\frac{26}{1000}$	„	$\times (73.7 - 36) =$	48 „
$1\frac{126}{1000}$	„	$\times (38.4 - 36) =$	3 „
$\frac{284}{1000}$	„	$\times (52.8 - 36) =$	5 „
$\frac{28}{1000}$	„	$\times (49.5 - 36) =$	1 „
		Unavailable descent going east,	238 feet.

The total ascent going east is - - - -		797.7 feet.
The total descent going east is - -	524.7 feet	
Of which there is unavailable, - -	238. "	
Leaving for the descent available in saving fuel,		286.7 feet.
And for the ascent to be overcome by the power of the engine, - - - - - -		511 feet.
The length of the Grave creek line is, as before stated, 218,090 feet; and consequently the average resistance offered by gravity to the progress of the freight train, going east, is $\frac{511}{218090}$ of the weight, or - -		572 lbs.
Add the ascertained resistance on a level road, - -		3217 „
And we obtain for the total resistance going east, -		3789 lbs.

We have now all the material requisite to compare the cost of working the Grave creek line, with such grades as have been selected for it by the Chief Engineer, with the cost of working a level road of equal length.

Resistance, going East.

3789 lbs. moved $41\frac{305}{1000}$ miles = 156,505 lbs. moved 1 mile.

Resistance, going West.

3089 lbs. moved $41\frac{305}{1000}$ miles = 127,591 lbs. moved 1 mile.

Total, east and west, - - 284,096 lbs. „ „

Mean, east and west, - - - 142,048 lbs. moved 1 mile.
Deduct the power required on a level (page 24), 132,978 lbs. „ „

Total increase of power due to the grades of the
Grave creek line, - - - 9,070 lbs. moved 1 mile.

From which it appears that when the Grave creek line is worked with engines capable of carrying their loads over all the grades, the power required to take an average load east and west over the whole line, would be within a fraction of 7 per cent. greater than the power which would be required to move the same load the same distance, if the line were perfectly level. But

7 per cent. on $41\frac{305}{1000}$ miles, is $2\frac{9}{10}$ miles.

From which we learn that the increase of power due to these grades is only equal to an addition of $2\frac{9}{10}$ miles to the actual length of the route, while that increase is set down by the Company's Chief Engineer at 33 miles, or more than *eleven times* its real value. But this is not all. The Chief Engineer not only stretches the virtual elongation of the Grave creek line one thousand per cent., but we shall presently see that he does this after having previously made an allowance sufficient to cover at least twice the whole cost of assistant power, in the supposition that *every freight train* is so large as to require aid. In other words, he first allows enough, and far more than enough, to enable the assistant power to do all the extra work which these grades occasion; and then, apparently, in order to make doubly sure that he *has* allowed enough, he adds 33 miles to the actual length of the line to account for that extra power which he had previously estimated fully twice over.

The cause of a portion of these remarkable errors has already been sufficiently explained. The Chief Engineer has confounded the angle of repose for the cars with the grade that doubles the resistance encountered by the whole train on a level road;—forgetting that the cars cannot move, even on a level track, until the locomotive is first put in motion; and that the engine cannot move until the steam has acquired sufficient force to overcome the pressure of the atmosphere on the pistons, as well as its own friction and that of its tender—and that it cannot attain any velocity without displacing the air in front. It is by overlooking all these forces that the Chief Engineer has exaggerated the virtual length of the Grave creek line about 25 miles, and then, by overlooking, in addition, the advantage which is due to the descending grades, that he has increased the error to 30 miles.

OF THE "EQUATED LENGTH" OF THE FISH CREEK LINE.

It is quite unnecessary to extend this examination to the Fish creek line. The grades upon that route have an inclination of $26\frac{4}{10}$ feet per mile, or less than the slope of uniform motion for trains descending by the force of gravity; and, consequently, as the power of the engine is sufficient to ascend every slope, the gain of power due to the gravity on the descending lines, is, in the aggregate, and for a circular trip, just equal to the loss on the ascending grades. The measured length of the line is, therefore, subject to no increase on account of the grades. It would, undoubtedly, be subject to such an allowance if the business of the road were of a character to justify the ordinary running of full trains, or larger trains than

the engine can draw up the grades. But such is not the fact. The freight is of a miscellaneous description, which will be sent, as it is now sent on the finished road, in trains of from 30 to 50 tons.

But, nevertheless, there is a loss of power—or waste of fuel—which belongs to this division of the subject.

The Fish creek line being 11 miles longer than the Grave creek route, it will require an extra depôt and an extra station, for fuel and water, at or near the mouth of the creek. The Chief Engineer estimates the time occupied by the freight trains in making the trip of $52\frac{27}{100}$ miles, at 239 minutes; while the time usually consumed by these trains at each station is about 15 minutes. The time required for the trip on this route is therefore increased 7 per cent. by this extra station. But during the delay the draft is retarded and the consumption of fuel reduced, probably one-half, or down to $3\frac{1}{2}$ per cent. of the total consumption on the trip.

This loss is equivalent to a virtual increase of the length of the line, so far as power, or its exponent, the cost of fuel, is concerned, of

$$3\tfrac{1}{2} \text{ per cent. on } 52\tfrac{27}{100} \text{ miles} = 1\tfrac{83}{100} \text{ miles.}$$

There is yet another source of loss of power on the Fish creek line, which also belongs to this division of the subject, viz: the increased resistance of the air consequent on the increased velocity of the trains: for, it is admitted, even by the Company's Chief Engineer, that the trains must run faster to make 52 miles in 4 hours than to make 41 miles in the same time—which is probably the only truth that his extraordinary equations do admit.

The difference between the relative speeds of the two lines—taking into the account the loss of time at the extra station—is about 33 per cent. The increased resistance of the air being as the square of the velocity, will be 77 per cent. greater on the Fish creek than it has been assumed to be in the preceding calculations, which were adapted to the speed designated by the Chief Engineer as proper for the Grave creek line.

The resistance of the air has been stated to be, for the freight trains on the Grave creek line, 50 lbs., and for the passenger trains 160 lbs.

If we add 77 per cent. to these values, we shall obtain for the increased resistance due to the higher speed to be maintained on the Fish creek line,

On the freight trains 50 lbs. $\times \frac{77}{100} =$ 39 lbs.
On the passenger trains 160 lbs. $\times \frac{77}{100} =$ 123 „

The increased resistance of the atmosphere due to the higher speed which is maintained on the Fish creek line will thus lead to an increased expenditure of power over that obtained for the Grave creek route, equal to $1\frac{1}{4}$ per cent. of the total resistance on a level, for the freight trains, and 6 per cent. for the passenger trains. We will not sensibly err if we take 4 per cent. for the average increase of power due to the increase of speed—which admits a very slight allowance for the adhesion of the air to the sides of the cars. But four per cent. on $52\frac{27}{100}$ miles is a fraction over $2\frac{9}{100}$ miles.

There is another cause of increased expenditure of power of far more importance than that here considered, as consequent upon the higher velocity required to be maintained on the Fish creek line. I refer to the in-

creased density of the steam due to the acceleration of the draft, and needed to produce and restore the higher velocity,—and to the *waste* of fuel consequent upon the increased excitement of the draft. But I propose to reserve this part of the question for special consideration.

We have now arrived at the following results.

Grave Creek Line.

The measured length of the Grave creek line is	41.305	miles.
Increase, when "equated" for grades, 7 per cent, or	2.891	„
Length "equated" for grades (exclusive of curvature),	44.196	miles.

Fish Creek Line.

The measured length of the Fish creek line is	52.27	miles.
Increased for loss at extra station, - - -	1.83	„
Increased for resistance of air due to higher velocity,	2.09	„
Virtual or "equated" length (exclusive of curvature),	56.19	miles.

We thus find that the "equated" elongations of these two lines, considered with reference to the expenditure of power which they respectively involve, are almost precisely the same—or 7 per cent. greater than the measured lengths; and that, consequently, we commit no appreciable error in comparing them with each other, by considering the power required to work them as proportional to their actual lengths. And this conclusion will hold true—precise enough for all practical uses—so long as the trains sent through are no greater than the power of the engine can control on the steepest grades. When we reach that limit, we come to the new problem of assistant power, which it will be my care presently to investigate.

But, before dismissing this division of the subject, it will be appropriate to call attention to the elastic nature of the "equation of distances," which the Chief Engineer has invented, apparently, to meet all cases of difficulty in which his peculiar and multifarious computations may become involved. In his controversy with Mr. Knight, in 1847, the "equated length" of the Grave creek route was assumed to be about 48 per cent. greater than its real length. But in the comparative estimates of February 15, 1849, the Chief Engineer discovered that the "equated" length should be regarded as 70 per cent. greater than the true length; and, finally, in the last revised estimate of his "Reply," he has concluded that both the other calculations were wrong, and that the "equated" length is just 100 per cent. greater than the *bona fide* length. In fact, this "equation" has a capability of stretching which fits it for every emergency.

OF CURVATURE AND ITS "EQUATION."

The Chief Engineer applies his "equation of distances" also to curvature, and with precisely the same success as has been witnessed in its remarkable application to grades. But here, also, he has discovered errors. In the report of 1845, he thinks that curvature was not estimated at all. In that of February 15, 1849, it was so applied as to increase the length of the Grave creek line within a small fraction of 4 miles; and in the last revised report—that of February 4, 1850—it is so modified as to increase the length of that line 8 miles.

I am obliged to say that each of these scientific guesses is erroneous, and that the last is by far the most erro-

neous of all. The first was the nearest right, the last is the furthest wrong.

But the Chief Engineer informs us, at page 38 of his "Reply," that he has ascertained from recent experiment that the resistance *to cars* passing around the circumference of a circle described with a radius of 400 feet, is twice as great as the resistance encountered by the same cars moving on a straight line equal in length to that circumference. Hence he deduces the general law that 360° of curvature is equivalent to an addition of 2512 feet to the measured length of the road.

Admitting the correctness of the experiments, and that the resistance of the cars is doubled, as asserted, on a circle 800 feet in diameter, the practical conclusion, for many reasons, is still wrong.

The total resistance of a freight train, moving at a speed of $10\frac{1}{3}$ miles per hour, and weighing, with the engine and tender included, 122 tons, it has been seen, is 3217 lbs., upon a straight and level road. But it is only the resistance of *friction* that is doubled on the curve; and as the friction is assumed by the Engineer to be $\frac{1}{264}$ of the weight of the train, it follows that 924 lbs. is, by his method, the increased resistance due to the curve.

The increase of resistance in the curve is therefore but $\frac{924}{3217}$ of the total resistance on a level road.

The error of the Chief Engineer, in this case, also, grows out of the incorrectness of his estimate of the power required to move the train on a level.

Applying this correction to the equation for curves ("Reply," page 38), we have for the increase of the actual length due to the curvature for the

Grave Creek Line.

$$7.992 \text{ miles} \times \tfrac{924}{3217} = 2.27 \text{ miles.}$$

Fish Creek Line.

$$8.888 \text{ miles} \times \tfrac{924}{3217} = 2.53 \text{ miles.}$$

But, let it be observed, this would only be the proper result if the Chief Engineer's experiments were correct. But these experiments are *not* correct, for they do not show the effect of velocity. It is impossible to have a faithful expression of the resistance on a curve, if it do not introduce the velocity of the train as an element;—for the resistance is a function of the velocity.

There is no principle in mechanics better established, or better understood, than the law of central forces. The centrifugal force is as the square of the velocity, directly, and as the radius of curvature, reciprocally. The elevation of the outer rail by no means neutralizes the effect of velocity, or the laws of central forces. In practice, it only reduces the friction, and that to a very limited extent. It reduces it on both roads perhaps in the same degree, leaving the curves of each road to contend with the speed at which they are respectively turned.*

Now, the speed on the Fish creek line is 33 per cent. greater than that on the Grave creek route; and if we assume that the experiments apply correctly to the average speed on the Grave creek line, the resistance must be increased, when applied to the other, in the proportion of $(1.33)^2$ to 1—or about 77 per cent.

We have then for the addition to be made to the respective lengths of the lines on account of

* I am not to be supposed to deny the correctness of the usual theoretical solution of this problem. I intend merely to maintain that the practical difficulties have never been overcome.

Curvature,

Grave creek line, as before, - - -		2.27 miles.	
Fish creek line, - - - - -	2.53	4.48	„
Increase, 77 per cent. for increased speed, -	1.95		

The actual and "equated lengths" of these two routes, corrected for curves and heights, and expressed in the mode adopted by the Chief Engineer, may now be finally exhibited.

GRAVE CREEK ROUTE.

Measured length, - - - - -	41.305 miles.
"Equated" for curves, - - - -	43.575 „
"Equated" for curves and heights, - -	46.475 „

FISH CREEK ROUTE.

Measured length, - - - - -	52.270 miles.
"Equated" for curves, - - - - -	56.750 „
"Equated" for curves, loss at extra station, &c.	60.670 „

OF THE APPLICATION OF THIS "EQUATION."

I propose now to make a single application of these "equations." I beg the pardon of your Committee for using that word, which has no legitimate relation to the thing which it is designed to express. But it has acquired currency with the Baltimore and Ohio Rail-road Company, and I should hardly be understood by them if I did not use it.

It will be observed that, by a total misapprehension of the nature of this problem, the Chief Engineer has obtained what he calls "equated distances," which show that the Grave creek line is virtually twice as long as the Surveyor's chain makes it appear: and that, after having thus doubled the length of the route, he uses this double

length for obtaining the cost of transportation—assuming, in the calculation, that every article which passes over that line, $41\frac{305}{1000}$ miles long, is actually hauled $82\frac{3}{10}$ miles. The excuse for doing all this is, that the grades are steep, and involve the necessity of greater power. But, after thus doubling the length of the whole line—or assuming that it is 41 miles longer than it is in fact—to account for these grades and this expense of power, he still makes a further allowance for *assistant* power—and *this last* allowance is, as before stated, of itself, fully twice as great as would be needed, if every train required aid, and all the extra work due to the grades were performed by the assistant engine.

I have, in the preceding pages, corrected this absurd equation, and exhibited its true value, obtained from admitted principles. I propose now to correct the estimate of the Chief Engineer ("Reply," page 43), by applying to his own facts, obtained from the experience of his own road, this corrected equation of distance.

I shall not, in this place, touch any of the quantities in that estimate, but such as appear under the head of "working," and involve the equated distances. The further corrections due to velocity, assistant power, maintenance of road, and the general expenses, will be taken up hereafter, each separately, and in its proper order.

The following estimate of the cost of working is based upon the quantities and prices stated on page 43 of the "Reply," but with a substitution of the true for the erroneous distances.*

* These prices are deduced from the true distances on the finished work, and they ought not, therefore, to have been applied by the Chief Engineer to his "equated" distances. But, as he has furnished the scale, I will not object to its use.

COST OF WORKING

GRAVE CREEK LINE.

Repairs, fuel, oil, &c.—	
250,000 tons × 46.475 miles × .363, - -	$42,176
250,000 passengers × 46.475 miles × .281, -	32,649
Repairs and grease of cars:—	
250,000 tons × 43.575 miles × .270, - -	29,413
250,000 passengers × 43.575 miles × .195, -	21,243
Assistant power (Chief Engineer's estimate), - -	11,232
Annual expense of working, - - -	$136,713
Equivalent, at 6 per cent. to a capital of -	$2,278,550

The "general expenses" are not included, because the same value is attributed to that item, in the Chief Engineer's estimate, on both lines—an error which will be corrected hereafter.

FISH CREEK LINE.

Repairs, fuel, oil, &c.—	
250,000 tons × 60.67 miles × .363, - -	$55,058
250,000 passengers × 60.67 miles × .281, -	42,621
Repairs and grease of cars:—	
250,000 tons × 56.75 miles × .270, - -	38,306
250,000 passengers × 56.75 miles × .195, -	27,665
Annual expense of working, - - -	$163,650
Equivalent capital, at 6 per cent. - -	$2,727,500
Deduct capital equivalent to cost of working the Grave creek line, - - - -	2,278,550
Difference in favour of Grave creek, - -	$448,950

We will now ascertain the relative merits of these routes, by taking as correct the Chief Engineer's estimate for construction, maintenance, assistant power and general expenses, and merely using the foregoing cost of

working deduced by correcting the errors in his equation of distance.

Estimate.

The Grave creek route is the cheapest to maintain, according to the Chief Engineer's estimate, ("Reply," page 42), by - - - - - - - - -	$160,991
And the cheapest to work, as above, by - -	448,950
Cheapest to maintain and work by - - -	$609,941
But dearest to construct, (Chief Engineer's estimate), by	319,253
Thus leaving for the superiority of the Grave creek route, in capital equivalent to the cost of construction, maintaining and working, the sum of - - -	$290,688

You will now observe that this result is obtained by merely correcting one of the Chief Engineer's errors—the error in his equation of distance. With that single exception, I have in no respect disturbed his estimate. I have taken his own cost of construction,—his own estimate for maintenance—his own monstrous allowance for assistant power—and have assumed, in conformity with his own assumption, that all the general expenses vanish on the 11 extra miles of the Fish creek line. More than this: I have left out of view the station and depôt at the mouth of Fish creek; have admitted the correctness of his own estimate of the wear of iron rails; and allowed nothing for the increased wear and tear of road and furniture due to the higher speed which is to be maintained on the longer route. Yet, with all these admissions, the mere correction of the equation of distance alone—without making any other change whatever—shows a balance of $290,688 in favour of the Grave creek line.

I propose, presently, to follow up this exposition, and

ascertain the value of the corrections to be applied to the other items of this extraordinary estimate. But, before engaging in this inquiry, I will ask your attention to some comparisons which I wish to make of the results exhibited in the estimates of February, 1849, and those of February, 1850—both comparing the same routes, with a view to the same object—the adjudication of the great question at issue between your city and the Company.

In the comparative estimates of February 15, 1849, condemning the Grave creek route by computations which I advised you were incorrect and indefensible, the Chief Engineer deduced for the total cost of conveying 60,000 tons through the Grave creek line—apart from the expense of constructing and maintaining the road—the sum of $17,625. This is equal to $7\frac{1}{10}$ mills per ton per mile.

In the comparative estimates of February 4, 1850, ("Reply," page 43), the cost of conveying 250,000 tons over the same line is estimated at $160,750 per annum, or $15\frac{6}{10}$ mills per ton per mile.

Now, I ask, can either of these estimates be trusted? The comparison of the two results shows that it costs more than twice as much to carry a ton when the trade is very large as it does when the trade is very small.

But, absurd as this is, in the matter of passenger conveyance the consequences are still more preposterous. In the comparative estimates first presented for your acceptance, the cost of conveying 150,000 passengers on the Grave creek line, was set down at $20,673, or $3\frac{1}{3}$ mills per passenger per mile.

In the comparative estimates of February 4, 1850, ("Reply," page 43), the cost of conveying 250,000 passengers on the same line, over the same grades and at the

same speed, is put down at $107,387, or 10½ mills per passenger per mile.

From this it results that, when the travel amounts to 250,000 persons, annually, it costs more than three times as much to convey each passenger as it did when the travel was 150,000 persons per annum.

In the comparative estimates of February, 1849, the repairs of locomotive engines were estimated as if the virtual length of that line were 45$\frac{3}{10}$ miles; but in the comparative estimates of February 4, 1850, these repairs are estimated for a length of 82$\frac{3}{10}$ miles; so that, in the course of a single year the Grave creek line has been stretched, in the mind and calculations of the Engineer, no less than 37 miles. The cost of repairing the engines which run upon it has increased in the same proportion. In the estimates of February 15, 1849, these repairs amounted to $\frac{11}{100}$ of a cent per ton per mile; and in those of February 4, 1850, to $\frac{34}{100}$ of a cent per ton per mile of the measured length. It costs, from this, about three times as much for repairs of locomotive engines for each ton hauled when the trade is large as when it is small.

But, the brother of the Chief Engineer—the learned counsel of the Company—has already furnished an explanation of these discrepancies. The comparative estimates of February, 1849, he replies with professional readiness, were not intended to show the *absolute*, but merely the *relative* expenses of working the two routes. But it happens that the same estimate contained also the estimated cost of *constructing* each of these lines. It now becomes, therefore, very essential to ascertain whether the cost of construction, adhered to in all the changes which are rung upon the estimates, is the absolute, or

only the relative cost. If the estimate of this item be of the absolute cost, then it is important to know by what process the Chief Engineer adds together the absolute cost of construction, and the relative cost of working, and the absolute or relative cost of maintenance, on the Grave creek route, and compares the sum with a similar aggregate for the Fish creek route. I should very much like to see *that* equation.

I regret that it is my duty now to pass from these absurdities to others which are worse.

MAINTENANCE OF THE ROAD.

I have no room in this paper for personal controversies; and I shall not, therefore, stop to discuss the correctness of the statements found at page 31 of my first Report, on the subject of the comparative cost of repairs for the Baltimore and Ohio road, during the years 1847, 8 and 9, which are denied by the Chief Engineer. My means of making these comparisons were all derived from the annual reports of the Company. My statements were, therefore, true, if the reports are true. But the Chief Engineer insists that the cost of repairs for 1848 were greater than those of 1849 for the track west of Harper's Ferry. That may possibly be so. It is a question which I have never discussed; but I am induced to apprehend that he is mistaken even on that point, and I shall therefore invite him to lay before the Board of Engineers, for their decision upon the questions at issue, the total cost of repairs for the whole road, and the separate cost of repairs for the portion west of Harper's Ferry, for the year 1849, duly attested by the Treasurer. He has access to the records and I have not.

There is another point on which the Chief Engineer attempts to produce the impression that I have misrepresented a fact concerning the statistics of his road, and which, though not pertinent to the matter immediately before us, I think it proper to notice in this place. In his "Reply" (page 48), he writes—"Mr. Ellet states "that the increase of tonnage on the Baltimore and Ohio "Rail-road in 1849 over 1848 was 80,000 tons!" And this error he considers so monstrous that he marks it with a note of exclamation, and then proceeds to state that, by referring to Table M., I would have discovered that the equivalent *through* tonnage of 1849 was 3600 tons *less* than that of 1848.

What I wrote in my first Report, as all that I write in this Report, I believed and do still believe, to be strictly true, notwithstanding the assertions of either the Chief Engineer or Table M. This is the authority for my original statement. The total tonnage for each year is given in the President's annual reports—thus,

For 1849, total tonnage (President's Report, page 6),	351,655 tons.
„ 1848, „ „ „ page 8),	271,252 „
Increase of 1849 over 1848, - - -	80,403 tons.

So far, then, the reports sustain, and do completely justify my remarks; yet I admit that the total tonnage might be 80,000 tons greater in 1849 than in 1848, and the equivalent through tonnage, notwithstanding, might possibly be greatest in 1848. But I had additional authority. It is stated on the first page of the President's Report of 1849, that the

Total receipts for 1849 exceeded those of 1848 by the sum of	$27,540 88
That the passenger receipts fell off, - - -	72,009 05
From which is deduced, for the *increased receipts from freight*, - - - - - -	$99,549 93

Then, conneeting the two facts, that the *total tonnage* had increased 80,403 tons, and that the *receipts from tonnage* had, according to the report, increased $99,550, with the words of the President, found on the very first page of his last report, "notwithstanding *the increase in the business of the road*, as indieated in the foregoing exhibit"—words which show that *he* also had been taught to suppose that the total business had greatly increased, although the travel had fallen off, I did really feel authorized in assuming that there had been this increase of tonnage, and that these statements, so put forth, were true, and accordingly reposed on them as if they were, in fact, true. But I will admit, in future, that they were false, and take the solemn assurance now given by the Chief Engineer—who had all the faets before him—that the through tonnage was 3600 tons *less* in 1849 than in 1848.

But I return from this digression to the subject in hand—the cost of road repairs.

As an evidence of the unfairness of taking the cost of repairs on the improved track west of Harper's Ferry, for the year 1848, as an exponent of the eost of maintaining the Baltimore and Ohio road, the Chief Engineer ("Reply," page 13), submits the following

TABLE

Of the Cost of Maintaining the Tracks of the Baltimore and Ohio Road during a period of 7 Years from 1843 to 1849, inclusive.

Years.	Total cost of repairs.	Miles of plate rail.	Miles of heavy rail.	Cost per mile of single track.	Tons of trade and travel over each mile.
1843	$82,499	104	116	$375	74,040
1844	98,791	104	46?	449	83,235
1845	88,185	104	116	401	98,700
1846	115,566	99	121	525	123,000
1847	127,751	77	143	577	176,000
1848	164,298	56	163	747	181,450
1849	194,981	42	178	886	163,805

We will now examine this table. It is stated by the Chief Engineer ("Reply," page 14), "that the number "of miles of track over which the trade and travel are "divided to obtain this result, is 220, embracing all the "main and second track daily passed over by the trains, "*and excluding all depôt tracks and sidings*, although there "are upwards of 9 miles of the latter." Now, I will respectfully suggest that, at page 35 of the Chief Engineer's Report for 1847, and at page 20 of his Report for 1848, there are tabular statements of the cost of repairs and length of each description of track, on the Baltimore and Ohio road. In each of these reports,—written without reference to the present controversy,—the length of single track is stated to be 208 miles (not 220), and the length of "siding and depot tracks" $21\frac{3}{8}$ miles and not 9 miles. If the reports are true, the Chief Engineer has, in constructing the above table, or, as he says, "to obtain this result," taken 12 miles from the depôt tracks and sidings and added that length to the main tracks—thus obtaining a larger divisor, and reducing, in that proportion, the apparent expenses for repairs per mile for each of the 7 years which the table embraces.

In his own Report for 1848 (page 20), the Chief Engineer states the cost of repairs per mile of single track to be $805; but in the present table he reduces the sum down to $747. In the Report of 1847, he states the cost of repairs for that year to be $614 per mile of single track, but in this table he has reduced the item down to $577. I do not wish to pursue these little matters. They are the mere straws which show the character of this controversy. The conclusions will turn upon more important facts and principles.

Again: I am at a loss to know how the Chief Engineer deduced the number of tons stated in the last column of this table. He says that the business is averaged over 220 miles of track. But if we divide the tonnage of the road, as it is stated in the annual reports, by 220, it will produce no such results as the table exhibits. For example: Taking the year 1846, we find for the

Total traffic,		
Tons carried one mile, - - - -		14,771,559
Passengers carried 1 mile, - - -	10,700,960	
Estimating two passengers as equivalent to 1 ton,		5,350,480
Total traffic in 1846, expressed in tons, - -		20,122,039

Now, if we divide this quantity by 220,—the number of miles over which, according to the "Reply," "the trade and travel and the repairs are divided"—we obtain for the average "tons of trade and travel over each mile," but 91,464. The tabular number is 123,000. I find the same discrepancies,—but following no regular rule,—running through the table. And, in every case which I have tested, the tabulated tonnage exceeds, by a very large figure, the real tonnage.

I do not know how this column of the table was constructed; but the practical effect of over estimating the tonnage and under estimating the cost of repairs, is to cut both ways—like a two-edged sword—into "the facts and the truth of the case." For this exaggerated trade is used on the next page of the "Reply" (page 14) as a divisor to that average charge per mile for repairs which had itself been produced by increasing the number of miles of track, and then dividing the whole annual cost of maintenance by the exaggerated distance.

The next point to which I ask attention is this: That the Chief Engineer does not fairly represent the cost of maintaining *a single track road*, when he adds together the whole length of single track and the distance on which the track is doubled, and divides that sum into the annual cost of repairs. But as he adopts that course, I will exhibit the full effect of it.

In my first Report I assumed for the cost of maintaining a single track road, - - - -	$982 per mile.
Additional cost due to the second track, - -	500 „
Cost of maintaining the Baltimore and Ohio road, with double track throughout, - - - -	$1482 per mile.
Reduced to the mile of single track, - - -	741 „

I will now compare this estimate with the actual average cost during the last 3 years on the same road—calculating in the same way.

1847—Repairs,	$127,751	on 208 miles,	$614	per mile.
1848 „	164,298	„	805	„
1849 „	194,981	„	937	„
Average of these 3 years, -			$785	per mile.

From which it appears that the average repairs on the

Baltimore and Ohio road, per mile of single track, for the last three years, calculated by the method of the Chief Engineer, exceeds the estimate contained in my former report by $44 per mile of single track, or $88 per mile of double track.

But the Chief Engineer's method is not the correct method of deducing the cost of maintaining either a single or a double track road; and as I seek the truth only, I wish to take no advantage of his errors.

The question before us is to determine the actual cost of repairs for a fair average year, from the latest and best experience of the Baltimore and Ohio Rail-road Company. And to arrive at a correct conclusion on this point, we will look into

The Experience for 1849.

In my first Report I used the experience of the year 1848, for the new track west of Harper's Ferry, as a fair index of the cost of repairs for the Baltimore and Ohio Rail-road, with a single track. The Chief Engineer asserts that this is an extreme case, as the track west of Harper's Ferry was that year in the course of its six and seven years' renewal. I have now before me the Report of 1849, which contains the latest information of that Company's doings; and as the road was in the best possible condition for presenting a favourable exhibit at the beginning of the year 1849, the selection of that year cannot be objected to by any one.

In the Report of the Chief Engineer for 1847 (p. 36), speaking only of the track west of Harper's Ferry, it is stated, in extenuation of the increased cost of repairs for that part of the road and for that year, that "The past

"year [1847] has been the *sixth*, and the present will be "the seventh year of duration, and these will have been "the years of greatest expense in its renewal; and by "the end of the *eighth* year, terminating October 1, 1849, "the whole wooden part of that section, 97 miles in "length, will have been renewed. The periods of decay "and renovation will not, however, come round so regu- "larly hereafter, &c."

And in his next Report—that of 1848—the Chief Engineer again accounts for the increased cost of repairs for that year over 1847, by the fact that the track west of Harper's Ferry, "was then in the *seventh* year since it "was laid, and was passing through the period of entire "renovation, &c." and promised the Board of Directors that "the repairs of the coming year would, however, be "very considerably lighter than those of the year just "closed." The "coming year" referred to the year 1849.

We thus find that the years of greatest expense on that part of the line, in the opinion of the Chief Engineer, would be the years 1847 and 1848, although a part of the renewals had been made as early as 1845 and 1846. The year 1849 was, therefore, to be *a cheap year*. More than two-thirds of the wooden part of the track west of Harper's Ferry, having passed through the process of renewal in the preceding years, there could not possibly be any extraordinary call for road repairs, until the return of the next rail-road cycle.

East of Harper's Ferry, at the beginning of the fiscal year, 1849, matters were in a still more favourable condition. The whole length of that part of the road is 82 miles; and of this distance there were 58 miles entirely

new, which had been laid with the rail most approved by the Chief Engineer, during the years 1846, 7 and 8. There were also, on this portion of the road, 19 miles of H rail-track, which had been in use ten years, but which had just passed through its periodical renovation, and entered upon the year 1849 in perfect condition. In fact, there remained east of Harper's Ferry, at the commencement of 1849, but *five miles* of the main track along which the heavy trade descends, that had not been completely renovated within the last three years.

At this time there must have been, of

Renovated Track.

West of Harper's Ferry, - - - - -	70 miles.
East of Harper's Ferry, - - - - -	77 „
Total length of track recently renewed, -	147 miles.
Length of road, - - - - - -	179 „
Track yet to be renewed on the main line, at the beginning of 1849, about - - - - - -	32 miles.

We thus find that, at the beginning of 1849, the timber of no less than 82 per cent. of the main line—over which the coal and other heavy freight is carried—was literally *new*, and that there remained but about 18 per cent. of that track on which it had not been recently and completely changed.

It also appears, from the reports, that the reconstructions east of Harper's Ferry (charged, of course, to capital account), had been effected at a cost, including the grading, of $755,213.

Now, we have to ascertain what was the actual cost of keeping up a mile of single track road from this experience—for no one will deny that the year 1849 must yield

results below a fair average for the cost of repairing any similar road after it has passed the infancy of its existence.

It might well be supposed that there is no necessity for this inquiry, since the cost is stated, at page 13 of the Chief Engineer's "Reply," to be just $886 per mile. But, I am sorry to say, that the Chief Engineer is so careless that his conclusions cannot be taken without special examination; and so regardless of correct principles that his application of facts, even when they are fairly ascertained, cannot be admitted at all. The tabular statement at page 13 is thus utterly wrong;—wrong as regards the tonnage conveyed, and equally wrong as to the expenses incurred.

The cost of repairs for 1849 is there set down at $886 per mile of single track, and the average of the sums there stated is used throughout the "Reply" as the cost of maintaining *a mile of single track road.*

I will therefore exhibit the mode in which this sum of $886 is deduced. The operation is curious, and the deductions from it still more strange.

The actual length of the road is - - - -	179 miles.
The actual length of second track is - - -	29 „
Total length of single track (see any An. Rep.)	208 miles.
Total cost of repairs for 1849, - -	$194,981

These are the facts. We will next look at the Chief Engineer's process.

He first assures us that it costs but $83 more per mile per annum to keep in repair two tracks than it does to maintain a single track ("Reply," p. 11). He next adds

12 miles to the actual length of the second track, and assumes that it costs $886 per mile to keep that second track, thus increased, in repair—having just stated, as the result of his proper experience, that it does not really cost over $83 to keep it in repair. He then multiplies the spurious length of the second track by $886 (instead of $83), and obtains, for the total cost of maintaining the second track,

41 miles of second track × $886 per mile, - - $36,326

The cost thus obtained, of keeping up this second track, he then deducts from the total annual charge for road repairs ($194,981), and finds a balance of only $158,655, for the cost of maintaining 179 miles of single track road. This sum of $158,655, is then divided by 179 miles, and the Chief Engineer thus obtains for the cost of repairs per mile of single track road just $886.

But, after a while (page 19), it becomes necessary to add to this cost of maintaining a single track road, the cost of the second track, so as to exhibit the total cost of a double track, as required by the law. This was managed with like skill. To deduce the cost of repairs for a single track, from experience obtained on a double track, he deducted, as we have seen, $886 for each mile of the second track. But, when working back again, and deducing the cost of a double track from the cost of the single track thus ascertained, instead of adding the $886 per mile previously deducted, he adds but $83 per mile, and thus commits an error of $803 for each mile of double track.

The double track has thus served as a balance weight, to be shifted as the emergencies of the calculation re-

quire. I do not charge these things, however, to design. Far from it—far be it from me to suspect any intentional misrepresentation. I attribute them entirely to that prevailing carelessness which runs through the Chief Engineer's reports on all subjects touching your interests.

Now, the process which I have described is adopted throughout the tabular statement at page 14, and it is for this reason that I have discarded that table, and all that is proved by it, as fictitious and wholly unworthy of confidence.

The fact is, that the cost of keeping the second track in repair is not $83 more than the cost of a single track, as is assumed by the Engineer when estimating the cost of a double track; nor is it $886, as he assumes when estimating the cost of a single track from experience obtained on a double track. The average of these sums is $485 per mile—which, I think, is very near the truth.

In my former Report I estimated this item at $500 per mile per annum,—a sum, indeed, not obtained from conclusive data, but yet the result of the most appropriate experience I could find.

The following estimate will represent the cost of keeping the Baltimore and Ohio road in repair during the year 1849, when 82 per cent. of the main line was new.

Estimated Cost of Road Repairs.

179 miles of single track road at $1008\frac{22}{100}$, - -	$180,481
29 miles of second track at $500, - - -	14,500
Total annual cost for 1849, - -	$194,981

which is the amount stated in the Annual Report.

It thus appears that, even when we assume for the cost of maintaining the second track of the Baltimore and

Ohio road, what I suppose to be near its true value—or $500 per mile—there results from the experience of 1849, for the cost of maintaining a *single track road*, when more than four-fifths of that single track had just been renewed, the sum of $1008 per mile.

This result cannot be disputed, if the Company's annual reports may be relied on.

It follows then, that, to keep one track in good repair, and always ready for the safe passage of a heavy trade, drawn by first class engines, and passenger trains at high velocity, will cost $500 per mile, even if no trade is actually sent over the line. To keep a double track, under like circumstances, in this condition, will involve a cost of $500 a mile for each track, or $1000 for the two.

If these facts are correct, then *the trade* of 1849—which the Chief Engineer states to have been equivalent to 163,805 tons—must have occasioned additional repairs, of which the value is $\$508\frac{22}{100}$ per mile—or $\frac{31}{100}$ of a cent per ton per mile, exclusive of the wear of iron; and the total repairs for a double track road, exclusive, likewise, of the wear of iron, estimated from the experience of 1849, is thus $1508 per mile.

The Chief Engineer estimates the constant expenses—or those independent of the trade—much lower than the experience of his road will warrant. If I had assumed that his estimate in that particular is correct, there would have resulted from the experience of 1849 the fraction $\frac{5}{10}$ of a cent per ton per mile, for the expenses due to the tonnage. But I consider his estimate wholly erroneous, and shall never take advantage of its errors.

In the future computations I shall correct the estimates ("Reply," page 42) by inserting for the

Constant expenses, with a double track, $1000 per mile.
Expenses due to the trade, - $\frac{308}{1000}$ of a cent per ton per mile.*

The Baltimore and Ohio Rail-road Company entered upon the fiscal year 1850, with a thoroughly renovated road, so that the "heavy eastward traffic now passes every where "upon a track of solid iron," and no appreciable renewals of perishable material will therefore be required. If the Chief Engineer's views be correct, the total cost of maintenance this year will be the same as that of 1843, or $375 per mile, with an allowance of $\frac{308}{1000}$ of a cent per ton per mile for the increase of trade.

It is upon that principle that he estimates the cost of repairs: and as I dispute the principle, it is proper that I should suggest a practical test of its accuracy.

On the 1st of May, 1850, the road completed its next fiscal half year, subsequent to the date of the last report. I have no means of knowing the result, but if the Chief Engineer be right the expenses for maintaining the roadway for that half year will be the half of the total expenses of 1843, or

First half of 1850 will be - - - - - $41,249
To which must be added $\frac{308}{1000}$ of a cent per mile for each ton by which the half year's trade of 1850 may have exceeded 37,020 tons, or - - - - - -

The Company will doubtless submit the experience of 1850, properly attested, to the Board of Arbitrators, and permit the allegation of their engineer, that the expenses of maintenance will return again to that afforded by the criterion of 1843, to be fairly judged by the practical results.

* My result, $\frac{31}{100}$, differs so little from that of the Chief Engineer, $\frac{308}{1000}$, for the variable expenses, that I make no change in that item.

As it is now entirely in their own power to settle this point by their own experience, I will not dwell longer upon it; but shall correct, in accordance with the proofs already adduced, the calculation of the Chief Engineer given at page 42 of his "Reply," in which the cost of repairs are assumed to be—

For graduation per mile, - - - - -	$ 96
For "constant" expenses, - - - - -	191
Total repairs, exclusive of injury caused by the trade, per mile,	$287

Repairs per ton per mile due to the trade, $\frac{308}{1000}$ of a cent, exclusive of the wear of iron.

For these numbers I shall substitute those above obtained, making for the value of this

CORRECTION,

Repairs, independent of trade, $1000, less $287 per mile, on 11 miles of extra road, - - - - -	$ 7,843
Which is equivalent to a capital of - - -	$130,716

If the Company produce their repair accounts for the year 1850, as far as they can be fully made up, and show by those accounts that their Chief Engineer is right, and that the cost of repairs in 1850 has returned to the scale deduced from the experience of 1843, of course I shall not insist on this correction. My whole wish is to arrive at the precise truth as shown by the most recent and most authentic experience of the Company.

I propose, therefore, to take one half the expenses of 1849, properly computed, and those of the first half of 1850 —thus uniting the two ends of the circle—as a fair average of the cost of repairs under the actual trade of the line.

Before leaving this subject, however, I must reply to

the Chief Engineer's question—"Why did he, [Mr. "Ellet] pass over the Boston and Worcester Rail-road, "a double track road as well as the Lowell road, of simi- "lar structure to the Western road, and, in short, a very "part and parcel of that road," &c.? ("Reply," p. 14.)

I passed over the Boston and Worcester road, because it furnished no data applicable to the subject which I had under discussion, while it opened a wide field for specious speculation and unjust conclusions. The Boston and Worcester Company, within the three years embraced by my comparison, and the year immediately preceding, had expended immense sums for the reconstruction of their whole road. These expenditures amounted, in that brief space of 4 years, to $40,000 per mile,—or an average of $10,000 per mile per annum, for the improvement of their work and its appendages. It was utterly impossible for the company, during this period of *bouleversement*—when they were tearing up the old tracks and putting down new, reconstructing the road bed and turning the whole work upside down—to keep accurate accounts, or properly to divide the expenditures between the cost of construction and repairs. To make use of such data for the true cost of maintenance, would have been to deceive and mislead the unwary reader, and hence, of course, I did not use them.

I think I have made the errors of the Chief Engineer on this subject so plain that they cannot do much more harm. Yet, at the risk of fatiguing your Committee, I will exhibit the facts in another form.

He states ("Reply," pages 11, 19, etc.) that the repairs of a single track, independent of the amount of trade, are fairly represented by $83 per mile. If this be

so, then the repairs, independent of trade, for the whole length of single track would be

208 miles, single track, at $83, - -	$17,264;

And, consequently, the total repairs of this description for *six years*,—the estimated period of natural decay,—would amount to

$17,264 per annum, for 6 years, - -	$103,584

Now, we may compare this speculation of the Chief Engineer with such pertinent facts as may be gleaned from the annual reports.

The expenditures for the purchase of new timber alone, for the repairs of track, amounted

In 1849 to - - - - -	$39,162
In 1848 to - - - - -	66,572
In 1847 to - - - - -	41,830
Expended for track timber alone in 3 years, -	$147,564

From which we find that the mere outlay for lumber with which to repair the track for *three years only* is nearly 50 per cent. greater than the total cost of those repairs for *six years* by the Chief Engineer's estimate. But, to this sum expended for timber, is yet to be added the cost of the labour of taking out the old stuff, distributing and putting in the new, and relaying the whole track. The value of this labour is fully equal to that of the material, or about $150,000 for the three years. And, in addition to this, the track cannot be kept in safe running order without a force of men to right it when displaced by heat and cold, sun and rain and frost—to remove the snows and prevent or repair intentional injuries. All these

things, including labour and lumber, the Chief Engineer estimates at $103,584 for six years—while the lumber alone did actually cost $147,564 for the last three years.

I do not attribute these things to intentional misrepresentation. But they are great oversights, and manifest most culpable carelessness.

OF THE WEAR OF IRON RAILS.

1. *Destruction of Iron on the Baltimore and Ohio Road.*

In my first Report on the matters now in controversy, I estimated the wear of iron rails by the data which I understood from the reports of the President and Chief Engineer, had been furnished by the proper experience of the Baltimore and Ohio Rail-road Company. But the Chief Engineer does not now admit that the estimate of the report from which I quoted was intended to represent the wear of iron alone; but maintains that it included the wear of iron and wood in the tracks, the wear of bridges, and under the "&c." contained in *another estimate*, he thinks that the estimate from which I quoted included "buildings, water stations, and all other appendages of the road."

Of course, if that is what the Chief Engineer meant by the words "Add for wear and tear of railway at $\frac{1}{4}$ of a "cent per ton per mile west of Harper's Ferry, and $\frac{45}{100}$ "of a cent per ton per mile east of Harper's Ferry, "averaging on the whole distance"—if that is what he meant, I certainly misunderstood him, and most unintentionally misrepresented his meaning. I could not help it, and am sorry for it.

But to avoid further mistakes I will pass from his former opinions to those last expressed.

First, he quotes the views of certain Commissioners in New York who had estimated the durability of a good track as equivalent to the duty of carrying 20,000,000 tons net. This extravagant estimate the Chief Engineer seems rather unwilling to endorse, but still quotes it as authority, then deducts 12,000,000 tons from it, and assumes that it is, in that shape, good scientific data.

But this *experience* he seems to think, even after his correction, needs strengthening by other testimony. He accordingly quotes certain estimates on the wear of iron made by some officer of the Reading Rail-road Company, to the effect, substantially, that a good track will bear 40,000,000 tons. After quoting this opinion respectfully, the Chief Engineer, without any explanation or apology, deducts the equivalent of 32,000,000 tons from it, and then finds that *it also* confirms his own views.

Now, with all due respect for the moderation of the Chief Engineer, I am compelled to say that he had just as much right to deduct 18,000,000 tons from the New York estimate as to deduct 12,000,000 tons; and just as much right to deduct 38,000,000 tons from the Reading estimate as to deduct 32,000,000 from it.

Both were absurd, as he well knew, but they were not rendered any less absurd by his mode of correcting and applying them.

We next observe that the Chief Engineer, after fortifying himself with the speculations of other gentlemen, and dealing most unceremoniously with their statements, repudiates the actual *experience of every road* on which the iron rails have been really worn out and changed, as

of no value. He seems to think that his own speculations are much more to be relied on than any well established facts.

The Philadelphia and Columbia road had, with less than a million and a half of tons, worn out the original plate rail, and its *two* subsequent "permanent tracks" of T rail, and a great deal of patching in addition. But the Chief Engineer attributes this result to a defect in the form, weight or material of the bar. This is experience, therefore, from which he can deduce nothing. He rejects, also, the worn out track of the New Brunswick and Jersey City road; that of the Long Island road; the first track of the Boston and Worcester road; the first *two tracks* of the Boston and Lowell road, and the first track of the Eastern road—all of which, in their day, were considered "permanent tracks," all of which were formed of T or H rails, and not one of which ever carried a million of tons net, or any thing like that amount, before its utter destruction.

The Chief Engineer says that these rails were all defective in form or weight or manufacture; and I admit that there is force in that objection to the *strict* application of the results which might be deduced from them. But it does not follow from the mere fact that they were obnoxious to these defects, that they would have sustained eight millions of tons, instead of the six or eight hundred thousand by which they were destroyed, if they had been as perfect as the very best rails that have yet been tested in this country.

Now, fortunately for the present object, it happens that there is one railway track which has never been condemned, as unfitting either in weight, figure or material;

and from which we may yet derive some useful instruction.

In 1837, the Directors of the Baltimore and Ohio Rail-road Company, desirous of availing themselves of the best experience in the country before adopting a plan for the reconstruction of their road, sent two able engineers on a tour of inspection of all the principal rail-roads then built or building in the States of Delaware, Pennsylvania, New Jersey, New York, Rhode Island, Connecticut and Massachusetts.

The gentlemen selected for this duty were Jonathan Knight, their experienced Chief Engineer, and Benjamin H. Latrobe, their ingenious and accomplished engineer of location and construction. These officers were eminently qualified for the duty assigned to them; they had ample time to do it well, and they accordingly reported the results of their labours in detail, in a work of 80 pages, illustrated by 12 large lithographic plates.

The Report recommended an H rail of 50 lbs. per yard. The suggestion was approved by the Board, and 19 miles of the road, east of Harper's Ferry, was accordingly relaid with that rail.

Now, I learn from table M in the report of 1848, that the total traffic carried on all parts of the Baltimore and Ohio road, since this track was laid down in 1838, is as follows:—

Years.	Passengers.	Tons.
1839	65,537	100,451
1840	65,216	88,374
1841	64,493	65,499
1842	60,002	67,843
1843	71,108	82,714
1844	74,661	103,110
1845	98,870	141,406
1846	123,107	193,915
1847	136,921	263,335
1848	160,974	271,252
Total for 10 years,	920,889 passengers.	1,377,699 tons.

But we find by comparing the *total tonnage* of the road with the equivalent *through tonnage*, year by year, that the equivalent through tonnage is but about one-half the total tonnage; while the equivalent through travel is almost precisely one-half the total travel.

The through tonnage is, therefore, about	690,000 tons.
The through travel 460,000 persons.	
If we adopt the Company's estimate, and assume that the wear and tear caused by two passengers is equal to the effect produced by one ton, we shall have, for passengers, - - - - -	230,000 „
Tonnage equivalent to the through traffic of the road, for 10 years, in freight and passengers, - -	920,000 tons.

Now, this estimate is subject to two corrections. Just where this H track is laid the Baltimore and Ohio road is provided with a double track, and the trade found above is divided between the two. But it is not equally divided between them, and I think we express the proportion of *wear* fairly when we assume that 550,000 tons have descended along the H rail, and 370,000 tons ascended by the lighter track.

But again. The trade on the eastern part of the road is somewhat greater than that on the western part.

To allow for this difference, we will add 100,000 tons to the foregoing result, and we will then obtain for the actual amount of trade which had passed over this H rail, to the end of the fiscal year, 1848, probably as near as it can be ascertained at all, 650,000 tons.

After using this H rail some four or five years, the Chief Engineer saw cause to believe that his road was still imperfect, and susceptible of further improvement. He accordingly recommended an entire change of construction, and the adoption of the inverted U rail for the residue of the line. But we find from the report of 1848, that before this U rail had been five years in use, or carried more than 400,000 tons, the opinion had become pretty generally prevalent along the line, that this last improved track was more defective than the H rail-track which it had superseded. In the language of the report, "an impression appears latterly to have prevailed, that "the description of track laid west of Harper's Ferry, in "1841 and 1842, and east of that point in 1846, 7 and 8, "is more costly to maintain, as well as to construct, and "otherwise imperfect, &c."

I do not mean to take any part in this domestic controversy, further than to say that it is doubtful whether the H rail track laid in 1838 is not the best track which has ever been introduced on the Baltimore and Ohio road. It is important, therefore, to ascertain, on competent authority, what was the condition of this track in 1848. It was the pride of the Company when put down, and might be justly appealed to as evidence of the sound judgment of the engineers by whom it was recommended.

I now quote from the Report of the Chief Engineer for 1848.

"It may be observed that the H rail track of the Bal-
"timore and Ohio Rail-road, laid on cross ties, appears,
"*although 4 years longer in use,* to have cost this year less
"by $176 per mile than the U rail west of Harper's
"Ferry with the string piece. But it is to be said, on
"the other hand, that although the H rail is the older,
"yet it has not carried much more than the other; as *the*
"*most of it is on a part of the road where the trade is*
"*divided between two tracks.* Moreover, *the iron* of the
"H rail had, when as old as the U rail is now, sustained
"much injurious wear, and although not many bars have
"yet been removed entirely from the track, *yet a great*
"*many are so far gone as to be nearly unfit for further*
"*service.*" And, on the same page, he adds, with great truth and force, "*when iron begins to go, its destruction*
"*advances with accelerated speed.*"

Now, let us put these several facts together.

We have already obtained for the amount of trade which has brought this excellent track of H rail, selected with so much skill and constructed with so much care, into the pitiable condition described by the Chief Engineer, about 650,000 tons. When it had sustained the wear of this amount of traffic—which, in fact, is very near the quantum that had destroyed the lighter rails of many other roads that we have rejected—some of the rails had been entirely worn out and replaced, a *great number* were so far gone as to be nearly unfit for further service, and destruction was advancing with accelerated speed.

This is the Chief Engineer's own account, and I sub-

mit whether this state of facts does not justify the conclusion that this excellent 50 lbs. edge rail was two-thirds worn. If this be a fair inference, then it will be destroyed when it shall have carried 975,000 tons.

Now, the cost of iron in such a track, if we assume $60 per ton as the average value of rail-road iron in this country, will be $4,800 per mile. The old iron, if sold, ought to bring about enough to pay for the cost of taking up one track and putting down the other, carrying off the old rails and bringing on the new, and the waste and loss of spikes, plates, rails and sleepers incident to the double operation.

The net cost of the change will, therefore, be about $4,800; and this sum, divided by the tonnage which will have destroyed the track—950,000 tons—will produce for the measure of its destruction, $\frac{5}{10}$ of a cent per ton per mile.

It thus appears that the actual wear of the best rail ever adopted on the Baltimore and Ohio road is equal to *half a cent* per ton per mile, or just double the amount at which I estimated the item in my first Report, on what I then supposed to be the authority of the Chief Engineer himself.

But, it may be said, that when the Chief Engineer described the condition of the H track in his Report of 1848, he was arguing in support of the policy of adopting the U rail, and that he may have been actuated by an overwrought zeal for the truth, and placed rather too much emphasis on the defective condition of the old track. With all due allowance for this consideration, I think that no one will doubt that the facts stated by the Chief Engineer are essentially true, and that this H rail was

not only rapidly wearing out, but is in fact nearly destroyed.

A careful analysis of the trade of those roads in this country, on which the iron rails have given way and been changed, will show that the destruction has been at the rate of $\frac{5}{10}$, and from that to $\frac{7}{10}$ of a cent per ton per mile.

Still, there is force and reason in the explanations which have been offered for each of these cases, viz: that the iron was too light for the engines which the rails supported; that the form of the bar was bad, or that the material itself was of inferior quality. Yet, while I admit the defence, I cannot admit that we have any right ever to hope for the selection of perfect iron, or the adoption of the best form of support, the best proportions of head and stem, or precisely the proper weight of bar, on any future road. We may allow something for admitted defects, but we must allow something also for the defects of the human judgment, for carelessness and even for frauds.

I believe, though there are no facts which will permit me positively so to assert, that this item of expense may yet be reduced down to my original estimate. That estimate was $\frac{25}{100}$ of a cent per ton per mile. I think that in the process of improvement, and with care and skill in the support and use of the rail, that limit may yet be reached.

The Chief Engineer in his "Reply" (page 42) estimates this item at $\frac{5}{100}$ of a cent per ton per mile.

The correction to be applied to that estimate is therefore $\frac{25}{100}$ less $\frac{5}{100}$ of a cent, or 2 mills per ton per mile.

Correction.

375,000 tons × 2 mills × 11 miles = $8250 per annum.

Equivalent capital, $137,500.

2. *Destruction of Iron Rails on the Western Road.*

The Chief Engineer alluded in his Report of 1848 to the wear of iron on the Western road of Massachusetts —the rail-road which he thinks more nearly "resembles "the Baltimore and Ohio road than any other existing "line." It is therefore legitimate to refer to the experience of that work on this point.

A large portion of the Western road is provided with a double track, of which the rail is very heavy—70 lbs. per yard—and the *change* of iron, or visible destruction, is consequently confined for the present almost entirely to that part of the line which has but one track, which has been longest in use, and which sustains the undivided action of the trains.

In 1849 the renewals of iron on this road cost $48,538. The length of track which that year had not been doubled, was $64\frac{1}{2}$ miles. The visible, or appreciable distruction was, therefore, at the rate of about $752 per mile of single track road.* The past destruction was, of course, a great deal less. The future destruction will, of course, be much greater.

This rail weighs $56\frac{1}{2}$ lbs. per yard.

The trade in 1849, estimating by the rule of the Baltimore and Ohio Company, two passengers as equivalent to one ton, was 304,000 tons.

This gives us for the wear of iron, per mile of single track, for that year, $\frac{25}{100}$ of a cent per ton per mile.

* Doubtless a portion of this outlay must have occurred on the double track, a proper allowance for which would reduce the average. But, on the other hand, considerable *renewals* of iron had been made in previous years on the single track, an allowance for which would *increase* the average.

In 1848, the wear on the same road, estimated in the same way, was $\frac{15}{100}$ of a cent per ton per mile.

In 1847, the wear on the same road, estimated in the same way, was $\frac{10}{100}$ of a cent per ton per mile.

I do not, however, quote these facts, relating to the destruction of a $56\frac{1}{2}$ lbs. rail, of good pattern and good quality, as indicative of the real average wear. I can scarcely doubt that this average will considerably exceed the result for 1849, for the track is still new; yet I think there is ground to hope that it may eventually, under a low price of iron, and with great skill and care in the management, be reduced to that limit.

3. *Destruction of Iron Rails on the Worcester Road.*

The experience of the Worcester road, on the wear of iron, will be useful here. The original rail, weighing 40 lbs. per yard, is condemned by the Chief Engineer as too light, and its early destruction is attributed altogether to that defect. I will not stop to dispute the fact, but seek for other data in the more recent experience of the Company.

In the year 1844, the Worcester road had a double track throughout—the old track weighing 40 lbs. and the new one, just put down, 63 lbs. per yard.

But in 1845, 6 and 7, this lighter rail was entirely removed, and a track weighing 66 lbs. per yard substituted in its place—the road-bed being, at the same time, gravelled and thoroughly improved.

In fact, the Company entered upon the year 1849, with two substantial tracks of modern make—one just five years old, of 63 lbs. per yard, and the other one year old

and weighing 66 lbs. per yard. There can be no fault found with either of these tracks.

In the year 1849, the wear of iron, determined from the cost of changing averaged upon the whole length of the road, was $438 per mile. But all this expenditure occurred on the track formed of the 63 lbs. rail, which was 5 years old—no part of the third track, 1 year old, having yet been changed. In fact, the whole of this expenditure must have occurred on 42 miles of the 63 lbs. rail—since about two and a half miles of that track had been worn out and changed during the three preceding years.

The total outlay for renewals, during the year 1849, on these 42 miles, was $19,530, or at the rate of $465 per mile.

But this result was produced by less than half the trade of the road, since the heavy trains descend on the more recent track, of somewhat stouter iron. I will not attempt to deduce the ultimate durability of this 63 lbs. track from the experience yet obtained; but I feel authorized by the facts that are now apparent, in drawing the conclusion, that this rail—fifty per cent. heavier than the track already destroyed—will most probably be unfit for safe service when it shall have sustained 50 per cent. more usage than its predecessor.

It cost last year $465 per mile for renewals, while carrying less than half the trade of the road; and "when iron begins to go," says the Chief Engineer of the Baltimore Company,—whose long experience gives great value to his opinions—"when iron begins to go, its destruction advances with accelerated speed."

COST OF SPEED.

OF THE EFFECT OF INCREASED VELOCITY ON THE REPAIRS OF TRACK.

In all the estimates of the comparative cost of maintaining the Grave creek and Fish creek routes, which have been offered by the Chief Engineer, the repairs of track and bridges have been charged at the same rate on both lines, without any regard to the greater speed of the trains on the Fish creek route. This difference of velocity he admits will be 25 per cent.; but if he had made allowance for the additional detention due to the extra station on the longer line, he would have found that the speed during the time of running must be fully 33 per cent. greater on that line to bring the trains out together.

In the estimate at page 42 of the "Reply" these repairs are still estimated as if they were independent of the velocity; but we have the sanction of the Chief Engineer himself,—expressed in his official reports, and before this controversy could be influenced by his opinion,—for all the allowance which I wish to make on this account.

In the Report of 1847, and again in that of 1848—both of which were printed by the Directors, and made the basis of tabular statements of the cost of maintaining their road,—a distinct admission of the influence of velocity on road repairs is made by the Chief Engineer. He there sets forth that, in dividing the total road expenses between the passenger and tonnage trains, he makes the division "by an estimate of the gross weight "of the two kinds of trains, compounded with the miles "run by each, *and allowing double wear and tear per ton*

"*to the passenger trains on account of their greater* "*speed.*"

This allowance of 100 per cent. in the wear and tear of road, it will be perceived, is made by the Chief Engineer solely on account of *the greater speed* of the passenger trains. This is the result of nearly 20 years experience; that the greater speed of the passenger trains causes an injury to the road for each gross ton, twice as great as the injury produced by the slower progress of the freight trains.

In fact, this conclusion has assumed the character of an established and settled truth upon the Baltimore and Ohio road; and though the estimate is not specifically endorsed by the present excellent superintendent, in his Report of 1849, yet it is very obvious that he has admitted its correctness and carried out his calculations for the year on the same assumption.

But we learn from the "Reply" (pages 29 and 30), that the actual speed of the passenger trains on the Baltimore and Ohio road is 79 per cent. greater than that of the tonnage trains. It follows, therefore, that an increase of 79 per cent. in the speed produces an increase of 100 per cent. in the cost of road repairs.

The speed required on the Fish creek line is nearly 33 per cent. greater than that which need be maintained on the Grave creek route; but, as the Chief Engineer estimates the difference at only 25 per cent. I prefer to take that number and give him the full advantage of his own published opinions.

Now, 79 per cent. increase of speed adds 100 per cent. to the cost of road repairs: hence 32 per cent. will be

the increased repairs due to an increase of 25 per cent. in the relative velocity.

Then, whatever be the scale adopted for the repairs of the Grave creek line, the long experience of the Baltimore and Ohio Company demonstrates, according to their reports, that the cost of repairs upon that line must be increased 32 per cent. to express the cost due to the higher velocity on the Fish creek route.

Your Committee must now appreciate the prodigious advantages possessed by that line which leads direct to your city, and will prevent its prostration. It is 11 miles shorter than the Fish creek route, and therefore relieved, in the first place, of the whole cost of maintenance and conveyance through that unnecessary space; while the speed of the trains being, according to the Chief Engineer's estimate, 25 per cent. less than that required on the longer route, the cost of repairs—not merely for the 11 miles, *but for the entire line* of 52 miles—will be reduced 32 per cent. The same considerations, we shall presently see, apply with equal force to the wear and tear of machinery, cars and engines, and to the consumption of fuel.

At present we will apply the facts obtained from the Reports of the Chief Engineer to the revised comparative estimates at page 42 of the "Reply."

I take the following items, which are dependent on the amount of trade and on the speed, from that estimate, for the maintenance of the Fish creek line.

Annual repairs of wooden superstructures, - -	$3,391
Annual repairs of track, due to the trade, - -	70,172
Total repairs dependent on the amount of trade,	$73,563

Now, these items are estimated at page 42 of the "Reply," as if the prices should be actually the same both on the Grave creek and Fish creek lines. There is no allowance whatever for the increased velocity of the trains on the Fish creek line.

This estimate, accordingly, needs the following

CORRECTION.

$70,563 increased 32 per cent. on account of an increase of 25 per cent. in the velocity,	- - - -	$22,580
Equivalent capital,	-	$376,333

We thus find, by restricting ourselves exclusively to the data furnished by the Chief Engineer of the Company, and distributed to the public by the President and Directors, that it will cost $432 per mile more to maintain the Fish creek line, with a traffic equal to 375,000 tons per annum, when traversed at a speed 25 per cent. greater than is requisite on the Grave creek line, than it would cost if the velocity were reduced to the same limit. But $432 per mile is only about *one-ninth part of a cent per ton per mile*—a quantity obviously much below its true value.

The fact is, this result is obtained exclusively from data supplied by the Chief Engineer, and applied without any change. But if I had made the corrections which I have already shown to be necessary, as well for the velocity as for the wear of iron, this item would have been increased to two-ninths of a cent per ton per mile.

Still, it is my wish to adhere as closely as possible to the estimates and facts which have been promulgated by the Company; and those facts show that the mere cost of maintaining the road-way of the Fish creek line is un-

derrated in their comparative estimates, by overlooking the effect of the admitted higher speed, in the sum of $22,580 per annum.

Thus far, I have rested entirely upon the authority of the Chief Engineer in estimating the value of speed. But there is other authority on this subject. It is a truth admitted among all engineers, that the cost of railway transportation increases rapidly with the increase of velocity. There are, indeed, differences of opinion as to the precise value of this element—some engineers considering the cost of the "*variable*" repairs of road and machinery as nearly proportional to the velocity; while others are disposed to regard the item as more nearly proportional to the square of the velocity.

In my own opinion, there are items simply proportional to the velocity; others proportional to the square of the velocity, and one, at least, proportional to the third power, or cube of the velocity.

The Chief Engineer has quoted the opinions of some one connected with the Reading Rail-road Company as authority; but it would be improper for me to rest any argument upon reports, the accuracy of which I have had frequent occasion to contest. Yet, while rejecting the publications of this Company as insufficient to establish truth, it affords me pleasure to express my confidence in the personal worth of the gentleman appointed by the New England Stock and Bond holders, to examine into the affairs of the Reading Rail-road, supervise its expenditures and suggest improvements in the management. Mr. David A. Neal was called to that duty after long experience on the rail-roads of Boston. In his last report, which is addressed to the Stockholders generally, he

treats this particular question in the following language: "On the road, it is believed, many improvements have "been introdueed. The regulation of eoal trains by "time-takers at eaeh station, ought to result in great be- "nefits. Irregularity in this particular is not only dan- "gerous but extremely expensive—*the cost of repairs*, "even without aecident, *increases in a geometrical ratio* "*with the spced.*"

This Company have had great experienee, and have gradually redueed the veloeity of their eoal trains down to 7 or 8 miles an hour; and the conclusion of the most responsible of their present offieers, expressed only a few months sinee, is, that the cost of repairs, even when no aceidents oeeur, inereases proportionally to *the square of the velocity*.

Aecording to this authority—the authority of the ehief offieer on a work introdueed by the Chief Engineer—the eost of road repairs would be 77 per cent. greater for the Fish ereek than for the Grave ereek line—which is more than double the estimate whieh I have dedueed from the data furnished by the Chief Engineer himself.

We may hereafter see that the estimate of Mr. Neal is fully sustained by the published eost of repairing loeomotive engines on the Reading road—the reports showing that it costs rather more to keep the passenger engines and tenders in repair for conveying one gross ton at high speed, than to keep the freight engines in repair when hauling 9 gross tons at a slow rate. But this is a matter whieh belongs to another braneh of our subjeet.

OF THE EFFECT OF AN INCREASE OF VELOCITY ON THE WEAR AND TEAR OF LOCOMOTIVE ENGINES.

In the foregoing pages I have only considered the effect of an increase of speed on the wear and tear of the track. We have yet to look at the wear and tear of the furniture, which will be attributable to the obligation of maintaining a velocity on the Fish creek line, sufficient to accomplish a trip of $52\frac{27}{100}$ miles in the time required to run but $41\frac{305}{1000}$ miles on the Grave creek route.

We have already seen that an increase of 25 per cent. in the speed, according to the experience of the Baltimore and Ohio Company, produces an increase of 32 per cent. in the wear and tear of the track. But, as it is the cars and engines that wear the road, we have a right to conclude—action and reaction being equal—that the road wears the cars and engines in the same proportion. We should therefore expect an increase of 32 per cent. in the wear of the trains of the Fish creek line, over and above that which is sustained by those on the Grave creek route.

But, by referring to Table K of the Report of 1848, we find that the wear and tear of freight engines was $\frac{171}{1000}$ of a cent per ton per mile, and that of passenger engines $\frac{90}{1000}$ of a cent per passenger per mile—and these quantities are employed by the Chief Engineer as equally applicable to both lines in the comparative estimates at page 43 of his "Reply." But, the condition of the problem is, that the Fish creek engines shall travel 52 miles while the Grave creek engines go but 41;—we are therefore compelled to correct the comparative estimates by an allowance sufficient to cover the additional wear and tear consequent on the increased velocity of the Fish creek

trains. That allowance is, as before, 32 per cent. We have then for this

CORRECTION,

$52\frac{27}{100}$ miles × 250,000 tons × $\frac{32}{100}$ × .171, - -	$7,150
$52\frac{27}{100}$ miles × 250,000 passengers $\frac{32}{100}$ × .090 - -	3,763
Additional annual repairs of locomotive engines due to the higher speed of the Fish creek line,	$10,913

Equivalent capital, $181,883.

This result is about equivalent to $1\frac{1}{2}$ cents for each mile run by the locomotive engines and their trains; which, in my judgment, is far below the truth,—for I believe that the cost of repairs increases with the velocity in a much more rapid ratio than is assumed in the Reports of the Chief Engineer, from which this measure is derived.

OF THE EFFECT OF AN INCREASE OF VELOCITY ON THE WEAR AND TEAR OF CARS.

This, with the large trade which we are here considering, is a very important item. It is the increased wear and tear of all the freight and passenger cars, composing 30 or 40 trains a day, by being compelled to traverse a space of $52\frac{27}{100}$ miles at a speed 25 per cent. greater than would be necessary on the shorter route.

At page 43 of his "Reply," the Chief Engineer has presented an estimate of the cost of maintaining the freight and passenger cars on both lines; but that estimate is vitiated by an unwarrantable elongation of the actual distances, under the process of "equating," which I have already fully exhibited.

I shall not here take advantage of that elongation for determining the allowance due to the increased speed. I prefer to take the facts presented by the Report of 1848, and apply them to the actual measured length of the route.

By that Report, we have, for the

Repairs and Grease of Cars,

250,000 tons, carried $52\frac{27}{100}$ miles at .270 cts. - -	$35,282
250,000 persons, carried $52\frac{27}{100}$ miles at .195 cts. -	25,482
Repairs of cars at ordinary speed, - -	$60,764

But the velocity is to be increased on this line, according to the estimate of the Chief Engineer, 25 per cent.; and if we admit that the cars are injured by acting at this increased speed upon the road, as much as the road is injured by the action of the cars, then, by the scale used in the Company's reports, an increase of 25 per cent. in speed will involve an increase of 32 per cent. in the cost of car repairs. The estimate at page 43 of the "Reply," is subject, therefore, to the following additional

CORRECTION.

$60,764, annual repairs, increased 32 per cent. -	$19,444
Equivalent capital, $324,067.	

This is about equal to $\frac{1}{11}$ of a cent per ton per mile, and $\frac{1}{15}$ of a cent per passenger per mile, as the increased cost of car repairs consequent on an increase of 25 per cent. in the velocity.

OF THE EFFECT OF AN INCREASE OF SPEED ON THE CONSUMPTION OF FUEL.

The necessity of maintaining a higher speed on the Fish creek line involves the consumption of a large addi-

tional quantity of fuel. The evaporation and pressure in the boiler are necessarily increased to supply the additional demand of the cylinders; and the draft is also increased by the additional exhaustion. But, instead of estimating this item by any à priori process, I will take the results of the actual experience on the Baltimore and Ohio road—where the accounts for the consumption of fuel by the freight and passenger engines are kept separate.

By referring to Table K of the Report of 1848, we find that the light passenger engines drew average gross loads but *one-half as great* as the average loads moved by the freight engines; yet the result was as follows:

Cost of Fuel.

For passenger engines, per mile run,	-	-	-	$10\frac{1}{3}$ cents.
„ freight engines, „	-	-	-	$6\frac{1}{4}$ „

From which it appears that the passenger engines, with half loads, consumed fuel which cost 65 per cent. more for each mile they travelled than that consumed by the freight engines with full loads.

Now, neglecting the difference between the gross weights of the respective trains, we find that an increase of speed of 79 per cent. occasions an increase of cost for fuel of 65 per cent.; and hence an increase of speed of 25 per cent may be reasonably assumed to involve an increased cost of $20\frac{6}{10}$ per cent.

It is not, of course, to be understood, that I mean to admit that there is a difference of only 25 per cent. in the speed on these two routes. I assume that limit merely because it is set by the Chief Engineer—preferring, even at some sacrifice of the overwhelming superiority of the

shorter line, to base my computations upon the facts admitted by the Company.

The comparative estimates at page 43 of the "Reply," assume for the consumption of fuel .160 cents per ton, and .172 cents per passenger, per mile.

The cost of this item on the Fish creek line, without any allowance for the increased velocity, will therefore be, according to the experience of 1848, as follows,—

Cost of Fuel.

250,000 tons carried $52\frac{27}{100}$ miles at .160, - - -	$20,908
250,000 persons carried $52\frac{27}{100}$ miles at .172, - -	22,476
Annual charge for fuel, - - -	$43,384

But we have just seen that an increase of 25 per cent. in the velocity will involve an increase of $20\frac{6}{10}$ per cent. in the cost of the fuel. Applying these additional data, we will then have the following

CORRECTION.

$43,384 annual charge, increased $20\frac{6}{10}$ per cent. -	$8,937
Equivalent capital, $148,950.	

The increased cost of fuel for the Fish creek line is thus about $2\frac{1}{3}$ cents per mile run by the trains—which is, I doubt not, considerably below the real effect upon the consumption which would be caused by the increased speed.

The result of this computation is somewhat affected by the greater cost of wood, which is used in larger proportion on the passenger, than on the freight engines. But this proportion will also be increased by the necessity of maintaining the higher velocity admitted for the Fish

creek trains. The estimate is subject, moreover, to a further increase in consequence of the lighter loads carried by the passenger engines. But I have no desire to swell the advantages of the shorter line by estimating every item at its full value, and carrying the reader through many minute computations, some of which would be laborious and complicated. I feel that I have ample margin, and therefore prefer rather to make slight sacrifices.

OF THE GENERAL EXPENSES.*

The Chief Engineer of the Company, in all his comparative estimates of the cost of maintaining and working the two routes at issue, has neglected to make any allowance whatever for this item on the 11 miles of extra distance occurring on the Fish creek line. He admits, however, that there is a legitimate charge, called "General Expenses," and that it must be estimated in determining the cost of working the Grave creek line. And his mode of ascertaining its value for that line is a very simple and reasonable one.

For this purpose, he turns to the Report of 1848, and there finds the amount of "General Expenses" per mile for the 179 miles of road already finished; and he then concludes that those of the $41\frac{3}{10}$ miles of the Grave creek route will be the same as experience has shown to have occured on $41\frac{3}{10}$ miles of the finished road. Accordingly, he so estimates these expenses for the Grave creek line. But, when he turns to Fish creek, he discovers the con-

* For an enumeration of the items constituting the "General Expenses," see First Report, pp. 19—27.

venience of a different law, and concludes, in effect, that, as we proceed from Baltimore to the West, the "general expenses" are strictly proportional to the distance, until we get to a point 380 miles from the city, when they suddenly cease entirely. The Grave creek line thus gets the full advantage of the general law, and the extra space of 11 miles on the Fish creek line the advantage of the exception, and escapes its application altogether.

Of course I repudiate all this, and consider it a very weak and untenable pretext for evading the clear propriety and necessity of estimating the "general expenses" on the 11 miles of extra and superfluous road which the Company choose to construct in the valley of Fish creek. But no pretext will serve. The 11 miles of additional distance exists, is avowed, must be maintained and worked, and cannot be maintained and worked for nothing. The same reason which justifies and compels the allowance for these "general expenses" on the 41 miles, justifies and compels the same allowance per mile on the remaining 11 miles. This cannot be avoided by any sophistry whatever, and the estimate of the Chief Engineer ("Reply," page 43) will therefore require the following additional

CORRECTION.

For the General Expenses on 250,000 tons, 11 miles, at .161	$4427
Do. on 250,000 persons, 11 miles, at .084	2310
Total correction for general expenses, - - -	$6737

Equivalent capital, $112,283.

Now, the Company's Chief Engineer has offered some excuses for the neglect to introduce these expenses on the 11 miles of extra road in his original comparative esti-

mates. It will be proper to notice those apologies in this connexion, for they are intended to stand as the excuse for overlooking the same items in the last comparative estimates of the "Reply."

I. *The extra depôt at the mouth of Fish creek.*—The cost of maintaining this depôt is not included in the comparative estimates, because, the Chief Engineer alleges, "the trade and travel on which the present estimates are "made is a *through* and not a *local* business—the latter "pays its own charges and brings an income not included "in that revenue, the expense of earning which we are "considering."

Now, what has this, I ask, to do with the matter? The law does not say that these estimates shall be made on an exclusively *through* business, but it clearly contemplates that the amount of business shall be the same on both routes, and that the estimates shall be based on the cost of carrying it *all*.

Of course, the business of these lines, as of all other roads, will be composed of through business and way business, though, for the convenience of computation, we may with propriety assume that it is all reduced, in the usual mode, to an equivalent through traffic.

It may well be, as asserted ("Reply," page 28), that the Company permit the depôts along the line to be maintained by individuals, who compensate themselves by taxing the produce which they receive. But this item in the cost of working the road is not any the less because the Company permit other individuals to bear the expenses and assess the tax on the trade, instead of doing it themselves. The charge is just as real, though it is collected through others in a somewhat unusual way. The road

itself might be kept in repair by third parties, who would draw their remuneration directly from the trade, without suffering the item to appear in the Company's accounts. But, the law is not to be evaded by any such process. The charge for maintaining depôts is a charge against the road, and will be greatest on the longer line because that line involves the necessity of an extra depôt.

II. *Water Stations.*—The reason assigned by the Chief Engineer for not estimating the cost of keeping up the extra water station which is required on the longer line, is that the cost of maintaining water stations "will be "proportional to the motive power expended upon each "line, which the water supplies; and as there is the most "power expended on the Grave creek route, there should "be the most of this expense thereon."

But this excuse is clearly an after-thought. There is no charge made against the Grave creek route in the comparative estimates, on this account. Besides, the fact is not correctly stated. When the Chief Engineer conceived the apology, he was labouring under the very erroneous impression which has controlled all his estimates, that the angle of repose for *the cars* is the angle of double resistance for *the train.* But this delusion has been fully exposed, and the fact established that the power on the Fish creek line is to that on the Grave creek line, very nearly in the proportion of 61 to 47—which only makes the reason assigned for omitting this item in the comparative estimates, worse for his case than the truth itself.

III. *Losses by fire.*—The excuse of the Chief Engineer for assuming that there are no losses from fire on the extra 11 miles is, "that the risk of fire is in proportion "to the power expended by the locomotive. and to the

"aeeompanying strength of blast, rather than to the dis-
"tanee travelled over."

But this does not meet the ease. Admitting the fact alleged, it eonstitutes no apology for the omission. The power expended, when eorreetly ealeulated, is found to be very nearly in the proportion of 61 to 47; while the "strength of blast," as well as the length of the line, happens to be mueh the greatest on the Fish ereek route. The speed on that route being 33 per eent. greater than is maintained on the other, the engine traversing it diseharges four eylinders full of steam into the ehimneys for every three eylinders full diseharged on the shorter line; and eonsequently, the draft, depending on the exhaust steam, is proportionably increased. The greater "strength of blast," the greater power expended, and the greater length of line all eoneur on the Fish ereek route; and, therefore, whether the "losses by fire" be proportional to the distanee, to the power or to the blast, these losses will be greatest on that line, from eaeh of these eauses seperately, and, à fortiori, from all of them combined.

IV. *Pumping water.*—The omission to estimate this item for the 11 extra miles, is also aeeounted for in the same way—under the assumption that the engines working the Fish ereek line exert less power in going $52\frac{27}{100}$ miles at a high speed, than those on the Grave creek line in traversing $41\frac{305}{1000}$ miles at a slower rate. But this assumption has been demonstrated to be unfounded.

The greatest expenditure of power, as already shown, oeeurs on the Fish ereek line; the most rapid exhaustion and the strongest blast likewise oecur on that line; the greatest distanee is there passed over; the speed is there the highest, and the greatest number of water stations is

there found and required. For each and all of these reasons, the expense of pumping water for the engines will there be greater than on the Grave creek route.

V. *The pay of clerks and agents, depôt labour* (at the extra depôt), *salaries, office rent, taxes, legal expenses, insurance and miscellaneous expenses*, are all regarded by the Chief Engineer as independent of the length of the line—the same, apparently, for a road 100 miles as for one a thousand miles long—and as occuring only at the terminal stations. But in his comparative estimates he violates his opinions, and considers that these expenses are strictly proportional to the distance for the Grave creek line, but only sink to nothing on the *extra* distance of the Fish creek line—although that extra distance involves the necessity of an *extra terminal station*.

I submit the decision of this point, without argument, to every reader's common sense.

OF THE ASSISTANT POWER.

In my first Report to your Committee I assumed that equal velocities would be adopted on both lines, and in that assumption made an appropriate allowance for the loss of *time* on the longer route. But the Chief Engineer in his "Reply" has preferred to consider that the trips shall be made in *the same time* on both lines, so that the speed of the trains on the longer line shall be materially increased. It follows, therefore, that in estimating the cost of assistant power we must take into view this increased velocity, so as to ascertain its effect upon the weight of the trains, and hence upon the number of trains requiring extraneous aid.

At page 33 of his "Reply" the Chief Engineer uses this language:—"Now it is supposed Mr. Ellet means "to say that while the principal engine is ascending the "maximum grades of the Grave creek route of $79\frac{2}{10}$ feet "per mile by the aid of the assistant engine, it is exerting "no more power, burning no more fuel, and subjected to "no more wear and tear than if it were traversing an "equal distance of the maximum grade of $26\frac{4}{10}$ feet per "mile of the Fish creek route. This might appear, in-"deed, without due investigation," &c.

It is unnecessary here to explain the meaning of language written to meet the assumption of equal velocities, since that is no longer a condition of the problem. But I will now say, that two heavy freight engines will carry a *load larger by* 78 *per cent.* up a grade of $79\frac{2}{10}$ feet per mile, *at a speed of* 8 *miles per hour*, than one of the same engines can convey up a grade of $26\frac{4}{10}$ feet, *at a speed of* 12 *miles per hour.* These are precisely the velocities which the Chief Engineer has prescribed for the two routes, in order to produce the same time upon each.

The solution of this question involves the use of De Pambour's formula, which will be found, with all the computations, in Note B. The results may be briefly stated here, as follows:—

A locomotive weighing 22 tons, with a tender of 15 tons, on a grade of $79\frac{2}{10}$ feet per mile, with a total pressure in the boiler of 80 lbs. per inch, and moving at a velocity of 8 miles per hour, can draw a train of cars and freight weighing 87 tons.

The same engine, on a grade of $26\frac{4}{10}$ feet per mile, at a speed of 12 miles per hour, under like circumstances, can draw a train of cars and freight weighing 97 tons.

We have then this proportion—

One engine on a $26\frac{4}{10}$ feet grade,	- -	97 tons.
Two engines on a $79\frac{2}{10}$ feet grade,	- -	174 „

Difference 77 tons: or, the two engines can convey 78 per cent. more tonnage up the steepest grades of the Grave creek line than a single engine can command—making the same through time—on the steepest grades of the Fish creek line. I will not pause to compare these facts with the aboriginal deductions of the Chief Engineer. This distinguished officer has attempted to compute the power of an engine without respect to the size of its cylinders, the evaporating capacity of its boiler, or any other element that affects the result; and he has endeavoured to compare the loads it would draw without regard to the velocity of its motion.

It is unnecessary to notice these primitive views; but it is important to ascertain what sum ought really to be allowed for the maintenance of assistant power on the Grave creek line, under a trade of 250,000 tons per annum. This annual business is equal to an average of 800 tons a day. The *average* load of each engine is 40 tons of freight; but the engines in use, if it be required, can convey 80 tons of freight and 90 tons of cars up the steepest grades on the route. Very few trains can therefore ever need the aid of extra power.

To view this branch of the subject properly we must ascertain what is the absolute tractile power of the locomotive. The foregoing calculations have been made on the supposition that we are confined to the rates of speed assigned by the Chief Engineer. But, we are under no obligation, in this comparison, to work the road at dis-

advantage because it suits an officer of the Company to suggest inconvenient and expensive conditions.

The maximum power of these engines is exerted when the speed is about $5\frac{1}{2}$ miles an hour. (See Note C.) When moving at this rate they are capable of conveying 970 tons, exclusive of the tender, upon a level line; which is equivalent to a load of 175 tons on an ascending grade of $79\frac{2}{10}$ feet per mile.*

Now there are, altogether, but $4\frac{1}{2}$ miles of steep grades ascending in each direction on the Grave creek route, and it is all embraced in a space of only 13 miles. If the engines are allowed to ascend these heavy grades at a speed of $5\frac{1}{2}$ miles per hour, and run the remaining $8\frac{1}{2}$ miles at a speed of 10 miles an hour, they will accomplish the whole space of 13 miles in the precise time prescribed by the engineer—or at an average speed of 8 miles an hour.

Hence a single engine, with help on the 13 miles where the steep grades are found, can carry 160 tons *of goods* through the line; and five such daily trains would therefore take the whole of the 800 tons of freight which we have assumed for the daily business of the road.

It is, therefore, clearly justifiable to say that there cannot be more than three daily trains requiring such help. In my first Report I assumed that there might be six; but that allowance was made, as before stated, under the condition of equal velocities on the two lines. This

* This is by no means an unusual performance. Eight years ago the Baltimore and Ohio Company had engines in use, weighing only 20 tons, and *capable of hauling* 1100 *tons on a level road, and* 170 *tons on a grade of* $82\frac{1}{2}$ *feet per mile, around curves of* 1000 *feet radius and at a speed of* 8 *miles an hour.* (See Report, 1844, page 13.)

condition has been changed by the Company, for the purpose of escaping the allowance for *loss of time.* A necessary consequence of the change is the adoption of so low a rate of speed on the Grave creek line as greatly to reduce the cost of assistant power, if not to supersede it altogether.

Now, the average cost of motive power on the Baltimore and Ohio road in 1848, for freight engines, was 19 cents per mile run. But the cost of maintaining these assistant engines will be much less than the average deduced from the working of the present line, for reasons already given. The speed of the assistant engine is but 8 miles per hour, while that of the principal engine on the Fish creek line is 12 miles per hour. The reduced velocity will be productive of reduced cost of repairs and reduced consumption of fuel: besides which, the labour of the engines, even on these ascending grades, is less than that of the Fish creek engines—and less than that performed by those on the finished road. Still, I shall make no deduction, but estimate the cost of running the auxiliary engine according to the rates deduced from the experience of 1848, or, at 19 cents per mile run.

Cost of Assistant Power.

There will be three daily trains over a line of 13 miles, making the distance daily travelled, 39 miles. I shall allow one-third more, and estimate for two circular trips, or 52 miles a day.

52 miles a day, at 19 cents per mile, for 312 days, gives	$3,082
Instead of the Chief Engineer's estimate ("Reply, p. 43),	11,232
Over-estimate for assistant power, -	$8,150

The revised comparative estimates, at page 43 of the "Reply," need, therefore, the following additional

CORRECTION.

For maintenance of assistant power, over-estimated by the Chief Engineer, - - - - - - $8,150

Equivalent capital, $135,833.

This error, like so many others exhibited in the estimates of the Chief Engineer, arises, in a great degree, from the habit of overlooking entirely the effect of increasing the velocity; and assuming that the load which an engine may convey is not increased by reducing its speed. There is no evidence in any of these comparative estimates, that the influence of velocity on the tractile power of the machine has ever received one moment's thought. He has thus entirely overlooked the great claims to superiority of the shorter line: and, at the same time, the prime objections to the longer one.

The engines upon the proportions of which the preceding computations are based, as is shown in notes B and C, are capable of conveying, on a level road, with a total pressure of 80 lbs. per inch,

At a speed of 5½ miles per hour, - -	970 tons.
At „ 8 „ „ - -	552 „
And at a speed of 12 miles per hour, but -	266 „

It will, in fact, require nearly four engines to haul a load at 12 miles an hour which one such engine can control at a speed of 5½ miles per hour.

But the Chief Engineer, in face of these demonstrated facts—facts recognised by every educated engineer of the day—makes no allowance for the effect of increased speed in reducing the load, or upon any item of expenditure, or indeed on any other question which he has examined touching this controversy.

But every one else will perceive that if we add 11 miles to the needful length of a road, we subject ourselves not merely to the cost of its first construction—the cost of running every engine and train of cars that pass over the work, whether for the service of the public or the road itself, to the necessity of traversing this extra space, and to all the cost of "working" for that distance—we not only subject ourselves to the necessity of maintaining that extra length of road *forever*, but we incur still more serious obligations. To place the longer line on a footing of equality with the shorter, we must work *the whole length* of that longer line at a higher speed—thus incuring greater risk of accidents, keeping up a greater pressure of steam, consuming more fuel, causing more injurious wear and tear of the iron rails and the wooden track, and doing more injury and causing more repairs to all the cars and engines in use. But the evil does not stop here. By being compelled to increase the velocity we must necessarily reduce the load; and, consequently, it requires generally no assistant power to enable the engines to surmount the steeper grades of the shorter line, where the speed is so much lower, with heavier trains than can be conveyed at the higher speed of the Fish creek line.

There is, in fact, not a single item in the long list of railway expenses, which is not injuriously influenced by an increase of speed. Yet, strange as it may appear, not a single one of these expenses has ever been considered or noticed in any of the comparative estimates of the Company's Engineer.

DEPÔT AT THE MOUTH OF FISH CREEK.

In my first Report to your Committee I estimated the cost of a depôt, &c., at the mouth of Fish creek, which had apparently been overlooked in the comparative estimates of the Company's Engineer, at $47,000, to be subsequently increased to $100,000, to meet the wants of a larger trade. But, instead of causing a modification of his report, my notice of this oversight elicited the following most extraordinary comment from the Chief Engineer ("Reply," p. 46). "This assumption of his own "[i. e. mine] grows out of his having gratuitously taken "it for granted that an intention is in the mind of the "Company to commit a fraud upon the law, and to defeat "its purpose of securing to Wheeling the practical bene- "fits of the terminus of the road. I need not dwell on "this very irrelevant and intrusive insinuation, as having "nothing whatever to do with the merits of the question "before us."

Now, I cannot restrain the expression of my surprise, that any officer of this company should, in an official communication to the acting President, pronounce an intention to be fraudulent, which has been openly avowed by the distinguished gentleman who last presided over the affairs of the Company, and whose views have received the sanction of the Directors, and been widely published by their authority.

In the Annual Report of October, 1847, the Company not only declared their intention—before a single survey was made—to construct the road by the mouth of Fish creek, but asserted that they had obtained a right, "*by the law*," to establish a depôt there, and even went so far

as to represent that the City of Wheeling had, in due form, assented to its establishment there. And they did not stop here, but intimated to their Stockholders that they contemplated a connexion with *both* the Ohio State works at the mouth of Fish creek, where this depôt was to be erected.

But the Chief Engineer now insists that this,—the plan of the Company,—would be "a fraud upon the law," and "defeat the purpose of the law," which was "to secure to Wheeling the practical benefits of the western terminus of the road." He therefore repels the bare idea as an "irrelevant and intrusive insinuation."

In answer to all this I have simply to say, that I have nowhere made or insinuated any such charge against the good faith of the Company; that the Chief Engineer did not receive this impression of their obliquity of purpose in any shape from me; and I fear, therefore, that the natural, and only possible conclusion is, that *he* suspected a fraud which *I* did not, and chose, from overwrought zeal, to volunteer a denial of the truth of his own suspicions. I made no such charge, and I did not suppose that the officers of the Company deemed the avowed intentions of the Directors to be dishonest, or that, under any probable state of facts, they would venture to make such accusations in their official reports.

That I may do no injustice to any of the parties, I will quote the precise language of the report, on those points which, in the opinion of the Chief Engineer, involve a contemplated fraud. I have never quoted these passages before, or ever alluded to them in any form. I would not refer to them now, if I were not compelled to do so in

protecting myself from the uncalled-for accusations of the Chief Engineer.

The Annual Report says, "With the assent of the "City of Wheeling, the Company is authorized by the "law, *to establish a depôt at the mouth of Fish creek*, and "Wheeling having, in due form, given her assent for that "purpose, the Company has the option, in extending the "road, to construct it to that point."

This avowed policy is what the Chief Engineer pronounces to be "a fraud upon the law." It must stand for itself, and be interpreted as it reads. I have too much respect for the Company to believe that they would elect a Board of Directors who could calmly meditate a purpose so unworthy; and I regret most deeply that the experience and long association of the Chief Engineer with those gentlemen, does not permit him fully to participate in that respect.

After thus declaring that they had obtained the right to build this depôt, and the option, in extending the road, to construct it to the mouth of Fish creek, the report further sets forth that "the central improvement in Ohio "may connect with this road on the river as advantage- "ously at Wheeling, or Fish creek, as at Fishing creek;" . . . . "and deeming it inexpedient to hazard the exten- "sion of their work upon the further legislation of Vir- "ginia, the Board thought the prosecution of their road "to Wheeling *by the mouth of Fish creek*, would insure "effectually a connexion with the Ohio works on both "the lines in that state, and still enable them to maintain "a successful competition with New York."

I do not intend to discuss this disagreeable subject further. I will leave the question of the extent to which the

carrying out of the policy here laid down in the Annual Report, may be considered as a violation of law and of fair dealing, to be discussed by the casuists in the Board, and their own distinguished Engineer. It is enough for me to see and to know that they had pre-determined, before a chain or a level was put on the ground, that the Fish creek route should be found to be the cheapest, and had declared their intention, in advance, to adopt that line, to build a depôt at the mouth of the creek, and thus, in the words of their Engineer, defeat the intention of the law and the contract, to give to the City of Wheeling the practical benefits of the terminus of the road, by there connecting with the Ohio works. This is enough to justify me in estimating the value of this depôt—for *it is to be built* if the Company can go to that point. The official report has announced the policy, and it will most assuredly be carried out, although the Chief Engineer may continue to declare that he deems that policy to be a fraud upon the law, and calculated to defeat its intentions. This is only his opinion, which will have but little weight in a judicial decision. In fact, the Company can have no object in going there but to build this depôt for the accommodation of those western connexions which are to prevent the City of Wheeling from becoming the substantial terminus of the road.

I therefore make the following

CORRECTION.

For depôt, &c., to be established at the mouth of Fish creek, in pursuance of the avowed intentions of the Company, - - - - -	$100,000

SUMMARY

Of the Corrections required by the Comparative Estimates of the Chief Engineer, found on pages 42 and 43 of his "Reply."

It has already been seen that, when the errors committed by the Chief Engineer in attempting to frame what he calls an "equation of distance," are corrected, without making changes or disturbance in any other item of his estimate, the Grave creek route was found to be the cheapest to construct, maintain and work, by the sum of $290,688.

But this amount was subsequently increased by the correction of further errors and oversights, as follows:

1. *Corrections for Road Repairs.*

Repairs of railway, independent of trade for the 11 extra miles of the Fish creek line, with double track, at $713 per mile per annum, -	$7,843	
Wear of iron rails on the extra 11 miles of the Fish creek line, 375,000 tons × 2 mills × 11 miles, - - - - - -	8,250	
Increased road repairs due to the extra 11 miles,		$16,093

2. *Corrections for Increased Speed.*

Increased road repairs for the Fish creek line due to the increased speed—per annum, -	$22,580	
Increased repairs of the engines on the Fish creek line, due to the increased speed—per annum, - - - - - -	10,913	
Increased repairs of cars on the Fish creek line, due to the increased speed, - - -	19,444	
Increased consumption of fuel on the Fish creek line, due to the increased speed, - -	8,937	
		61,874

3. *Correction for General Expenses.*

General expenses on the 11 miles of extra road on the Fish creek line, omitted entirely by the Chief Engineer, - - - -		6,737

4. *Correction for Assistant Power.*

Assistant power, over-estimated on the Grave creek line, to be corrected by an allowance on the Fish creek line equivalent to the over-estimate, - - - -		8,150

Correction for Station at the mouth of Fish Creek.

Depôt, station, &c., at the mouth of Fish creek,		6,000
Total correction for the most prominent errors,		$98,854
The capital equivalent to this annual charge is	$1,647,560	
To which must be added the superiority of the Grave creek line, obtained by correcting the Chief Engineer's equation for distances, -	290,688	
Total superiority of the Grave creek line in the cost of construction, maintaining and working, with a trade of 250,000 tons and 250,000 passengers per annum, - - - -		$1,937,248

Your Committee is aware that there has never been any stability in the estimates offered to you by this Railroad Company, which, from the outset to the end, are as shifting as the sands of the Missouri. You can never say they are *here* and lay your finger on them. Before you can pronounce "presto" they are gone. You crush their calculations down with the weight of irresistible truth, and they have another set of figures and a new "equation" ready to take their place. They add, without hesitation, 30 or 40 miles to the measured length of a line, if their purposes need such an elongation; or they

double or treble their estimated cost of conveyance, with out an explanation or an apology, if the emergencies of the case require that particular change of front.

In replying to such calculations all we can do is to take *the last*, and assume *that* to be the position on which they mean to rest. I have here, accordingly, taken their latest comparative estimate, and corrected it, so as to make it conform as much as possible "to the facts and the truth of the case." You have seen the result—which shows for the superiority of the Grave creek line over that which, in pursuance of an early and fixed determination, they had decided to adopt, the sum of $1,947,248.

It will be recollected that, in my first Report, I deduced for the equivalent capital which, expressed in the form contemplated by the law, exhibited the superiority of this same line, with the same trade, the sum of $1,278,000. The cause of the increase which is here observed, is easily explained. It was, in fact, pointed out in the first Report (p. 80), and arises, almost entirely, from the increased velocity which the Company's engineer has decided to adopt for the Fish creek trains.

In that Report I assumed that the velocity should be the same on both routes, and made a moderate estimate of the value of the time lost in traversing the 11 miles elongation of the Fish Creek line. To escape from the necessity of allowing for this lost time, the Chief Engineer abandoned the condition of equal velocities originally assumed, and in his "Reply" substituted the hypothesis of *equal times*. The consequence of this change has been to compel me to make appropriate estimates of the increased wear and tear of road and furniture, cost of fuel and reduction of loads, on the longer line, which this in-

crease of speed necessarily involves. This allowance for wear and tear and fuel, and diminished useful effect—as I anticipated in my first Report—greatly exceeds the proper allowance for the loss of time. But, both the estimates are legitimately deduced from the premises. It is, so far as your interests are concerned, of little importance which we take, and you can well afford to allow the Company to make their election. In my opinion it is more appropriate to allow for the loss of time, than to compel the Fish creek trains to make the trip in the same number of hours that is required on the shorter line, at such ruinous sacrifices.

But, if the Company choose the condition of equal velocities, the value of the time which is lost on the longer route will turn the scale against that line; and if they choose equal times, the increased velocity on the longer route will involve still greater expenses and show a larger balance against it. In fact, the value of time, fairly estimated; the value of the increased speed justly deduced; and the equation of distance correctly computed, will each be sufficient, of itself, to decide this question in favour of the Grave creek line.

I abstain from further comments. The principles of estimation laid down in my first Report were just and rational. I do not wish to change them or to modify the results. The different route pursued in this Report has been imposed on me by the new conditions prescribed by the other party.

It is with extreme regret that I have found myself compelled to differ so widely from the various estimates of the Chief Engineer of the Company, which have been submitted for the information of the Legislature of Virginia and the

acceptance of your eity. But great interests are involved in this issue. The vested rights, the hard earnings and future prosperity of a city of twelve thousand people, are threatened with vital injury, by the determination of a powerful Company to over-ride the law, pervert the facts, evade their written eompaet, and triumph, if they can, against truth and right.

Such things should be resisted; and I have endeavoured, by a simple and clear exposition of the specious errors by which the end was to be attained, to prevent the threatened wrong. I can do but little more. My present health is scarcely adequate to the further duties which this eontroversy will probably involve. Your case will now rest entirely with sworn arbiters, eminently qualified by education and experience to decide upon its merits. Whatever may be your natural anxieties for the momentous issue, I have an unshaken and abiding confidence in the result.

Respectfully,

Your obedient servant,

CHARLES ELLET, Jr.

Civil Engineer.

NOTES.

NOTE A.

The following is the demonstration offered by the Chief Engineer of the Baltimore and Ohio Rail-road Company, for the equation of distance, in the Appendix of the Report of 1838. I quote the demonstration *entire*, and literally.

"*Equations of the Elevations and Curvatures to Horizontal Distance.*

"1st. *Elevations.* Every $26\frac{4}{10}$ feet of height to be overcome is equivalent to one mile of horizontal distance. That is, the lifting of a load upon the rail-way here considered through that vertical distance causes the consumption of as much mechanical power as the propulsion of it through a mile of straight and level road—as shown below.

"The above proposition being not equally true for every weight of train, with a given weight of engine and tender, the inclination of the way required to double the resistance varying as the ratio of the engine and its load varies, it is demonstrated here with reference to the assumed weight of the *tonnage* train, composed as follows:—

"Weight of engine, 12 tons; tender, 7 tons—Total, -	19 tons.
"Gross weight of train of 12 double cars, *influenced by friction*, - - - - - - - - -	102 ,,
Total weight of train *influenced by gravity*,	121 tons.
"Friction of 102 tons upon a straight part of the way, 11.20 lbs. per ton, - - - - - -	1142 lbs.
"Increase of friction due to the *mean* radius of curvature, which will be half of that due to the *extreme*	

radius (of 573 feet), the latter being taken at 35 per cent. of 11.2 lbs. = 3.92 lbs. ÷ 2 = 1.96 lbs. per ton, 200 lbs.

" Total resistance from friction of train and curvature, of load of 102 tons, - - - 1342 lbs.

" Total resistance, from gravitation of 121 tons, 1355 „

" Total resistance on ascent of $26\frac{4}{10}$ feet per mile of engine and train, - - - 2697 lbs.

" The half of which is $1348\frac{1}{2}$ lbs—differing from the resistance upon a level part of the way curved with the *mean* radius, by only $6\frac{1}{2}$ lbs.

" The power to be exerted by the above engine may then be considered as doubled on the grade of $26\frac{4}{10}$ feet per mile, in the conveyance of the above load, at a speed equal to that with which it is drawn on the level portions of the road—and, consequently, in passing over a mile of such a grade, twice the moving force is expended. It is a well known principle of mechanics, that in the conveyance of loads up inclined planes, the same amount of power is expended in lifting the load to the same height, let the inclination of the plane be what it may. So that the above proposition will hold for all grades, as well those above as those below $26\frac{4}{10}$ feet per mile, with this provision, however, that if the engines used upon a railroad are constructed with a view to plying upon the grade specified, with a given maximum load, then, upon all steeper planes, either heavier and more powerful machines must be used, or assistant engines brought into requisition."

The foregoing *demonstration* is taken, word for word, from the Chief Engineer's Report. I wish merely to call attention particularly to the fact that, on the level road, *no resistance is included but that arising from the friction of the cars alone*, whether the train be following a straight line or passing around a curve. The friction of the engine, the friction of the tender, the resistance of the air and the atmospheric pressure on the pistons, are all overlooked. And this is what is called a *solution*.

I proceed with the demonstration.

" 2d. *Curvatures.* Every complete circle of 360°, resulting from the aggregate of all the angles turned upon a line of railway, produces an amount of resistance, and demands an amount of moving power, equiva-

lent to the propulsion of the load through an additional horizontal distance of 1256 feet—as shown below.

"By experiment upon the Baltimore and Ohio road (see 7th Annual Report, p. 117), it has been determined that the resistance from friction, in a curve of 400 feet radius, is one and a half times that which it is upon a straight part of the same railway, both parts being level. The resistance from curvature being inversely as the radius, it will of course be the double, in a curve of 200 feet radius, of that which it is in one of 400. Consequently, in the curve of 200 feet radius, the resistance will be twice as great as upon a straight line; and in the conveyance of a load through the circumference of a circle of that radius, which is 1256 feet, very nearly, there will be twice as much power exerted as upon a straight line of equal length—and upon every entire circle of 360°, let the radius be what it may; or the radii as various as they may in the turning of that number of degrees, there will be the same virtual addition of 1256 feet to the distance through which the load must be propelled—for, although, as the radius increases the resistance at any one moment diminishes, yet the length of the curve being increased in strict proportion to the increase of its radius, the final amount of resistance is the same; by a perfect analogy to the case of inclined planes of different degrees of inclination, but surmounting the same vertical height.

"In the above calculations the resistances due to the *friction of the engine and tender are left out of the question*, and the *useful* effect of the machine alone considered. This omission simplifies the propositions without taking from their truth."

It might have been added, that the *velocity* with which the curve is turned, is also left out of the question; an omission which, perhaps, helps to increase the *useful effect*.

The reader has now seen the whole "demonstration;" and he will have a clearer head than La Place or La Grange if he can understand it.

NOTE B.

The following is De Pambour's formula for the load which a locomotive engine of known proportions can draw at a given speed.

$$M = \frac{m\,\mathrm{P\,S\,D} - \rho\, d^2\, l\, \mathrm{V}}{9\,\mathrm{V\,D}} - \frac{\mathrm{F}}{9}:$$

In which expression he represents by

M, the number of gross tons of the load, tender included;

F, the friction of the engine without load;

D, the diameter of the wheel expressed in feet;

d, the diameter of the cylinder, also in feet;

l, the length of the stroke in feet;

P, the *total* pressure (or atmospheric pressure included) of steam in the boiler, expressed in pounds per square foot. Supposing these engines to be worked under a total pressure of 80 pounds per inch $P = 11{,}520$ lbs.

p, the atmospheric pressure expressed in pounds per square foot, or $p = 2117$ lbs.

S, the *effective* evaporating power per hour; which, in these engines, will be taken at 70 cubic feet of water per hour.

m, the ratio of the volume of the steam at the *total* pressure P to the volume of water that has produced it;—in this case $m = 360$.

V, the velocity of the engine in feet per hour.

The proportions of the freight engines used in this report will be found in the text at page 13. Substituting the values there given, in the above expression for the load which an engine can draw at the speed of 8 miles, or 42,240 feet per hour, we shall have

$$M = \frac{360 \times 11{,}520 \times 70 \times 4\frac{1}{2} - 2117 \times 1.42^2 \times 2 \times 42{,}240}{9 \times 42{,}240 \times 4\frac{1}{2}} - \frac{440}{9}.$$

Reducing this expression we obtain for the value of the load

$$M = 506 \text{ tons.}$$

But the *ton* employed by De Pambour is 2240 pounds. The value of M, in tons of 2000 lbs., is therefore

$$M = 567 \text{ tons.}$$

The result of this computation shows that, when the pressure in the boiler is 80 lbs. per inch, this engine will draw a gross load, tender included, of 567 tons, at a speed of 8 miles an hour on a level road. Deducting 15 tons for the tender, the load of cars and freight will be 552 tons.

We wish now to know what load this same engine will draw at the same speed, and under the same circumstances, on a grade of $79\frac{2}{10}$ feet per mile—which is equivalent to a slope of very nearly 1 in 67.

We have seen (page 17) that the engine exerts a power when moving with its tender only,—

On a level road, of - - - - - -	2,537 lbs.
If to this we add the friction of the cars with the above load,	
or 552 tons at 8 lbs. per ton, - - - -	4,416 „
And the *additional* friction of the engine for 552 tons at 1	
lb., or - - - - - - - -	552 „
We obtain for the total resistance, with a full load, on a level	
line, - - - - - - - -	7,505 lbs.

To ascertain the load which will produce this same resistance on a plane rising at the rate of $79\frac{2}{10}$ feet per mile, or 3 feet in 200 feet, involves a simple equation, which need not be introduced here. The result however is, that, when the load, exclusive of the tender, is 87 tons, the engine will ascend this grade of $79\frac{2}{10}$ feet, and exert the same amount of power as was required with a load of 552 tons on a level.

We have next to determine, for a level line, the load which corresponds with a speed of 12 miles per hour—that assigned by the Chief Engineer for the most difficult portions of the Fish creek line.

For this purpose we substitute in the formula for the value of V, 63,360 feet per hour. Making this change in the notation we obtain

$$M = \frac{360 \times 11{,}520 \times 70 \times 4\frac{1}{2} - 2117 \times 1.42^2 \times 2 \times 63{,}360}{9 \times 63{,}360 \times 4\frac{1}{2}} - \frac{440}{9}.$$

From which we deduce for the value of the load,

$$M = 251 \text{ tons;}$$

which, reduced to the ton of 2000 pounds, is

$$M = 281 \text{ tons.}$$

If we deduct the tender the load will be 266 tons.

From which it appears that the same engine which was capable of conveying a load of 552 tons of cars on a level road at a speed of 8 miles an hour, can only convey 266 tons—*or less than one-half*—at a speed of 12 miles an hour.

Such is the advantage of saving 11 miles of distance. Besides enabling us to reduce the velocity, and thus save wear and tear and fuel, it permits us, by so reducing the velocity, to increase immensely the ordinary loads of the engine.

The next point to be determined is, the load which this same engine

can convey at the same speed up the steepest grades of the Fish creek line—or $26\frac{4}{10}$ feet per mile. Here we have,

Resistanee of the engine without load, on a level line, as before	2537 lbs.
Add frietion of cars with 266 tons at 8 lbs. - -	2127 „
„ for additional frietion of the engine with 266 tons at 1 lb.	266 „
Total resistanee, with full load on a level line, -	4930 lbs.

The resistance whieh this engine will have to overeome on a grade of $26\frac{4}{10}$ feet per mile, with a load of 97 tons, at the same speed—12 miles per hour—will be the same as this.

We find, therefore, that, when employing first elass engines of the proportions here given, they will be eompetent to the following relative

Performance.

Load on a level line, at a speed of 8 miles per hour, -	552 tons.
„ „ „ 12 „ „ -	266 „
„ a grade of $79\frac{2}{10}$ feet per mile at a speed of 8 miles per hour, - - - - -	87 „
„ a grade of $26\frac{4}{10}$ feet per mile at a speed of 12 miles per hour, - - - - -	97 „

We thus pereeive that the engines on the Fish creek line ean earry but 13 per eent. more weight up the grades of that line, at the veloeity fixed by the Chief Engineer, than they ean eonvey up those of the Grave creek line at the speed whieh he assigns for the grades of that route.

But I do not admit the propriety of this arrangement of the relative speed, and hesitate not to say that one of these engines can convey 100 tons, or, if need be, 175 tons, by a well ehosen distribution of the veloeities, over the Grave ereek line, in either direction, *without assistant power and in less time* than the same load ean be earried by the same engine through the Fish Creek line. [See Note C.]

NOTE C.

Of the Maximum Load of the Engines.

The following is De Pambour's formula for the maximum load which an engine may draw with a given pressure of steam in the boiler.

$$M = \frac{(P - \rho)\, d^2 l}{9\, D} - \frac{F}{9}.$$

Substituting in this equation the values obtained from the known properties of the engine, we have

$$M = \frac{(11{,}520 - 2117) \times 1.42^2 \times 2}{9 \times 4\frac{1}{2}} - \frac{440}{9};$$

which being reduced, gives us for the maximum load,

$$M = 880 \text{ tons},$$

or its equivalent, 985 tons of 2000 lbs.

The net load, exclusive of the weight of the tender, is therefore 970 tons.

The corresponding load, on a grade of $79\frac{2}{10}$ feet per mile, will be just 175 tons.

The *speed* with which this maximum load will be conveyed, is expressed in feet by

$$V = \frac{m\,S\,D}{d^2\,l}.$$

Substituting the numerical values, as before, for the notation, we have

$$V = \frac{360 \times 70 \times 4\frac{1}{2}}{(1.42)^2 \times 2} = 28{,}350 \text{ feet},$$

or very nearly $5\frac{1}{2}$ miles per hour.

From this we learn, that the same engine which can draw 970 tons, on a level road, at a speed of $5\frac{1}{2}$ miles an hour, can convey but 552 tons at 8 miles, and but 266 tons at 12 miles. Such is the effect of an increase of velocity on the tractile power of the machine.